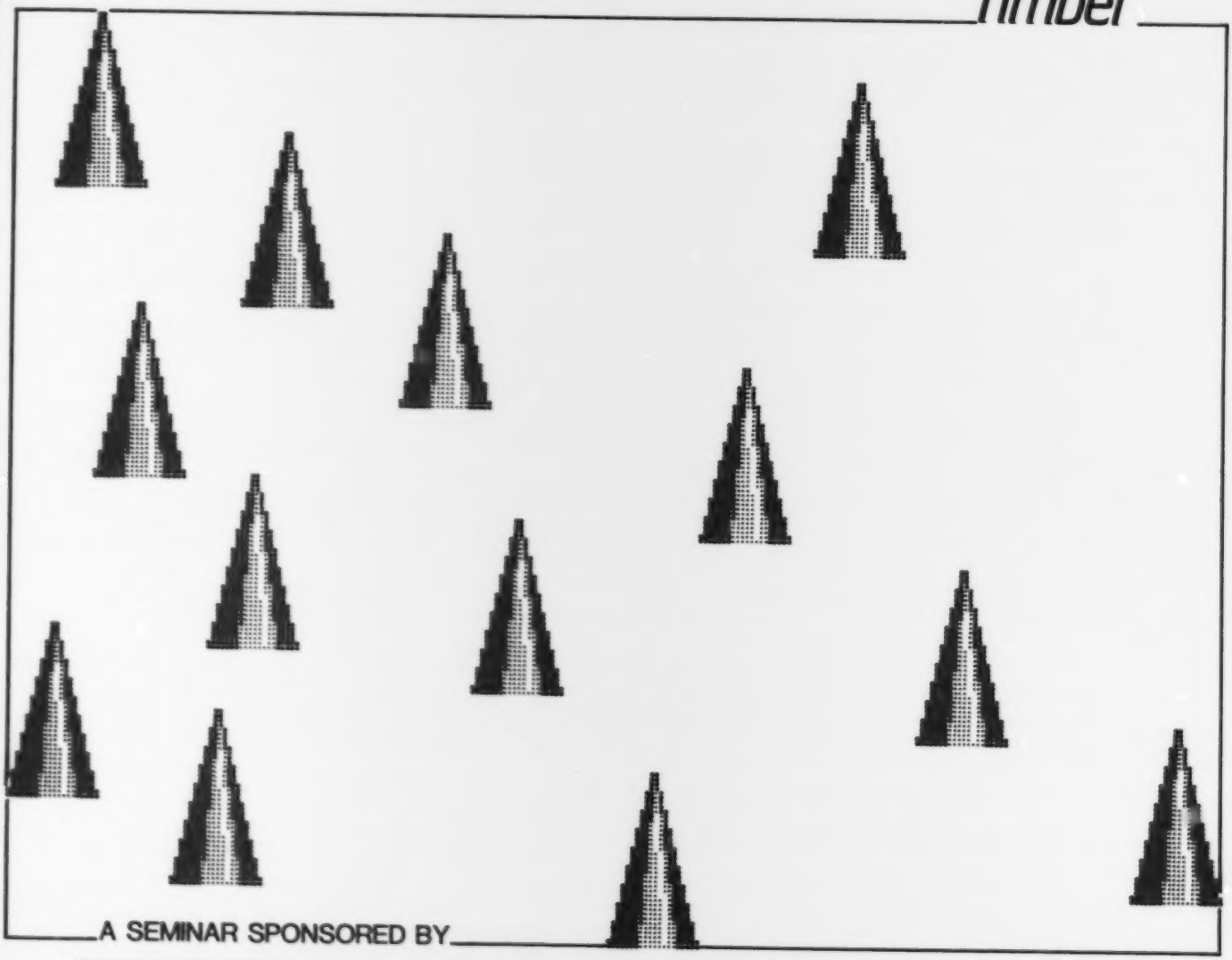
Harvesting and Processing of Beetle-Killed Timber

Proceedings



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HARVESTING AND PROCESSING OF BEETLE-KILLED TIMBER

Proceedings of a Seminar Sponsored by
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Edited by

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TABLE OF CONTENTS

	Page
Foreword	1
Timber Salvage Policies - Goals and Strategies R. Truant	2
Beetle-Killed Pine Processing Problems and Opportunities: a British Columbia Perspective R.W. Nielson	6
Salvage and Storage of Beetle-Killed Timber D. Giles	10
Harvesting and Processing of Beetle-Killed Pine D. Giles	15
Processing Beetle-Killed Timber into Veneer and Plywood R. Reiter	18
Processing Dead Timber into Veneer and Plywood D. Walser	20
Volume and Value Recovery from Live and Dead Lodgepole Pine M.E. Plank, T.A. Snellgrove and T.D. Fahey	27
Sorting of Dry and Green Lodgepole Pine Before Kiln Drying R.W. Nielson and J.F.G. Mackay	31
Infestation by Pine and Spruce Bark Beetles in British Columbia and its Effect on Kraft and Mechanical Pulping P.R. Thomas	35
Utilizing Lodgepole Pine Forests of the 21st Century: a Research Program P. Koch	48

FOREWORD

Never in the history of the forest industry in the B.C. Interior has so much dead timber been salvaged.

A continuous series of natural forest disasters has contributed to this situation. Mountain pine beetle attacks on lodgepole pine have created the most extensive and persistent problems since the early 1970's. Spruce bark beetles and forest fires, however, have more recently added large forest areas to be salvaged and processed.

This seminar was initiated by the Northern Interior Lumber Sector of the Council of Forest Industries of B.C. and organized by Forintek Canada Corp. It focussed on the particular problems associated with the salvage, harvesting and processing of beetle-killed timber in the B.C. Interior. It brought together the collective experience and expertise of industry, provincial government and research organizations; and provided a forum to discuss relevant issues, problems, and possible ways of reducing the negative impacts of beetle-killed timber.

Special thanks are offered to Mr. J.F. Whitmer (Chairman, NILS/COFI) for his thoughtful opening remarks, and to Mr. R.W. Stephens (Director, Forintek Western Region) for moderating the program.

TIMBER SALVAGE POLICIES - GOALS AND STRATEGIES

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Since the late 1970's, bark beetles have played a major role in the harvesting operations in the southern portion of the Prince George forest region.

This is not to say that they first appeared on the scene at this time, as large volumes of spruce were killed in the 1960's.

Spruce beetle, mountain pine beetle, Douglas-fir beetle and more recently, western balsam bark beetle have had a significant impact on development planning and forestry operations within the region.

Since 1978 there has been an annual green attack of between 40,000 and 70,000 hectares, mainly involving the spruce bark beetle. The annual harvest of beetle wood has been 4,000,000 - 5,000,000m^3.

Before getting into the main topic of my report, I would like to briefly discuss the overall regional beetle strategy and the statutory and contractual requirements which apply to the harvest of beetle attacked wood.

The strategy is divided into three main components: Detection, Containment, and Control.

Under Detection we consider:

- aerial recci's,
- aerial grid surveys,
- ground recci probes, and
- ground grid probes.

Under Containment we consider:

- harvesting,
- trap trees, and
- pheromone baiting.

In this report, the concentration will be on harvesting

The final step is Control, under which we consider:

- access development,
- pheromone baiting,
- lethal trap trees,
- single tree disposal, and
- small scale harvest.

Statutory requirements are:

Ministry of Forests Act, Section 4, which defines the purposes and functions of the forest service. In particular, Section 4(b) directs the forest service to manage, protect and conserve the forest and range resource of the Crown.

In the Forest Act there are seven sections which relate to beetle attacked timber:

- Sections 12(e) and 28(d)(iii) which require the holders of forest licences and tree farm licences to prepare management and working plans;

- Section 88 which allows certain costs to be offset against stumpage;

- Section 125 which provides the authority for the regional manager to order the holder of an agreement or owner of private land to take appropriate measures to control or dispose of insects:

  Related to this section is Section 161 which makes it an offence for anyone to fail to comply with an order made under Section 125. Besides making it an offence, Section 161 allows the Crown to recover any costs it has incurred as well as the value of the Crown timber destroyed or damaged as a result of the failure of compliance;

- Section 127 permits the regional manager to enter into agreements for the control and disposal of insects or disease on forest land and for sharing the costs of control and disposal;

- Section 128 which allows the minister to make agreements with other governments, municipalities, regional districts, or any person for insect and disease suppression.

Contractual requirements are:

- Condition 3.05(a) of Forest Licences and Condition 2.06(c) of Tree Farm Licences require the licensee to provide, through the management and working plan, for provisions to protect the forest from damage by fire, insect or disease;

- Condition 3.03 of the Forest Licence and Condition 2.04(a) of the Tree Farm Licence permit the licensor to require the licensee to amend the management and working plan to harvest timber damaged by fire, wind, insects and disease.

I have dealt specifically with the statutory and contractual requirements of the major tenures, which are the forest licence and tree farm licence. There are similar requirements for holders of timber sale licences (major) and wood lots.

That covers the statutory and contractual requirements, and we can now direct our attention to the ministry and regional policies regarding beetle attacked timber.

It is Ministry policy to protect or enhance the forest resource by preventing or reducing losses from beetle attack. In order to accomplish this, the ministry has a stated objective of harvesting all beetle attacked timber as quickly as possible so that the timber is utilized before it starts to deteriorate.

Although the various statutory and contractual requirements I have just discussed are in place, the ministry prefers to look upon the harvesting of beetle killed wood as a partnership agreement between the forest service and the industry, with the industry responsible for those areas in which they operate, that is, their approved planning areas in a timber supply area or the tree farm licence area, and the forest service responsible for all other areas.

The key implementation vehicle on industries part is the management and working plan and the development plan.

The ministry also sees a significant industry role, through the timber supply area steering committee, in developing plans to control and/or harvest beetle infested stands as they occur within a timber supply area.

More recently (April 22, 1985), the new tree farm licence subsidiary agreement has come into effect. This agreement formalizes the partnership concept and lays down what each respective partners' responsibilities are with respect to insect and disease detection and control:

1) Licensees' responsibilities:

- Monitor the tree farm licence for pest occurence and impact, and advise licensor of situations requiring immediate attention;
- Conduct timely and effective pest management programs and participate cooperatively with the licensor in pest control operations;
- Incorporate pest management prescriptions into harvesting and silvicultural activities;
- Obtain pesticide use permits as required.

2) Licensors' responsibilities:

- Conduct audits to ensure that proper pest management activities are being carried out;
- Provide consultation on pest management and pesticide use;
- Coordinate pest detection between licensee, the forest service and the Canadian Forestry Service;
- Coordinate pest management programs when more than one tenure is involved;
- Review Section 88 proposals, approve those applicable, issue addendum and adjudicate costs claims.

3) Accountability and penalties:

- Failing to meet obligations may result in: (1) billing the licensee for the licensor's cost of pest detection and/or control, or; (2) suspension of operations.

A similar agreement for forest licence holders is presently being developed.

Costs of industry participation in beetle management activities are recognized by either the appraisal system or through Section 88 of the Forest Act.

Section 88 provides that credits under stumpage payable may accrue to a person for certain work performed that is not considered in the determination of stumpage rates.

Projects eligible for credit under Section 88 include bark beetle management, but exclude salvage logging and work carried out in compliance with Section 127 of the Forest Act.

The following activities may be considered for funding under Section 88:

- aerial surveys, to produce overview maps of infested areas;
- ground probes to lay out a single tree treatment program;
- single tree treatment programs;
- trap tree programs outside of active or proposed cut blocks where traps will not be removed while adjacent timber is being harvested;
- pheromone placement in conjunction with a single tree treatment program and for containment of beetle populations within active or proposed cut blocks;
- broadcast burning where the intent is specifically for beetle population reduction.

In order for projects to be eligible for payment:

1) The work must be approved in advance by the regional manager,

2) The costs estimates must be approved by the regional manager,

3) The work must be performed to the satisfaction of the regional manager.

HARVESTING STRATEGY

Before I commence, it should be clarified that my comments relate basically to the spruce bark beetle infestation in the Prince George area. I feel, however, that many of the comments can be related to any type of beetle attack.

Once the extent of any attack is known the first objective which has to be met is the establishment of a harvesting goal that complies with Ministry policy, which is reducing losses and insect populations.

The first questions that have to be asked and answered relate to allowable annual cuts. Some of these questions are:

- How much allowable annual cut is traditionally available in the specific areas under attack?
- Is the traditional allowable annual cut sufficient to handle the infestation?
- If the traditional allowable annual cut is not sufficient to handle the infestation, can other allowable annual cut be moved into the area?
- Should priorities be set with regard to the movement of allowable annual cut?

In the case of the Prince George spruce bark beetle attack, the harvesting goal set was that all infested timber should be harvested within two to three years from the date the stand was attacked.

It was also established that harvesting should concentrate in green, moderately and heavily attacked stands with the intent of reducing beetle populations and hopefully the intensity of future attacks. Moderate attack is defined at 6-30 percent attack and heavy attack as 31 percent, plus.

At this stage, it was also decided to set a priority on what allowable annual cut would be used to meet the objectives. Basically, four priority categories were set. In order of priority these were:

1) Established industry allowable annual cut traditional to the area,

2) Small business sales,

3) Established industry allowable annual cut not traditional to the area,

4) District manager sales.

As the licensees operating in the attacked areas harvested the timber, it soon became apparent that the traditional cut could not handle the situation and that additional allowable annual cut should be moved into the area. Therefore, in sequential order the following allowable annual cuts were moved into the area:

- Small business allowable annual cut,
- The allowable annual cut of established operators, traditional to the area, but who had allowable annual cut in other areas of the timber supply area where there was no beetle problem,
- The allowable annual cut of established operators who were restricted by their licence as to the species they could harvest. Relief was granted to this type of licensee to permit them to harvest beetle attacked timber.

One question which was asked, but not acted upon, was that of moving into the area the allowable annual cut of established operators who did not have traditional cut in the area. No action was taken because in the planning process it was decided that the forest service would not pose any undue hardship on a licensee.

All the allowable annual cut moved into the area was done with the consent of the licensee.

Everything I have discussed up to this point in our strategy involves harvesting at a level which is chargeable to the approved allowable annual cut of the timber supply area.

The rate of harvest I have just described did not accomplish our goal of harvesting the timber within two or three years of attack and we had to look at harvesting additional volume over and above the approved allowable annual cut.

In this process it was determined that any volumes sold over the apportioned allowable annual cuts would be sold by the auction process. First priority would be given to overcutting the small business program and second priority was to advertise district manager sales. District manager sales are sales open to bidding by anyone including the established industry.

That, basically, was the strategy for making the allowable annual cut available to harvest the attacked timber. Harvesting the timber then became our major concern and one of the main limiting factors was the question of road access.

The area in question contained large tracts of land which did not have developed road access. This posed problems for both the forest service and industry. A lack of funds, both in Section 88 and the ministry budget, meant that most roads had to be built through the stumpage appraisal system.

In addition, it was virtually impossible to build the amount of road required in a short time.

As a result, roads were built as harvesting progressed up a valley. This meant that priority areas were not harvested as soon as they should have been.

It was also discovered that not only was lack of access a problem but that existing access roads had limitations as to the amount of traffic that could be handled.

In some cases, existing access problems were handled by modifying road use patterns, for example one way systems and 24 hour a day hauling and in other cases the amount of traffic had to be controlled by the volume of timber sold tributary to the road.

The problems of road access development may become somewhat alleviated this year by the establishment of two funds:

1) The small business enterprise program fund which will allow the construction of roads into small business sales. This fund is to be perpetrated by having all the bonus bids from small business sales go into the fund;

2) The emergency pest fund which may provide some money for the development of access roads into areas of attack or potential attack.

Other harvesting conditions or requirements which were varied because of the attack were as follows:

1) Cruising - Normal cruise requirements applied except that comparison cruises could be used provided the areas were similar in nature.

2) Appraisals - normal appraisal procedures are applied. There has been no pre-set policy established which would qualify certain areas to have the minimum stumpage regulation apply. The minimum stumpage regulation means that stumpage is set at 1/4 of the prescribed rate. Any areas which are felt to qualify for the minimum stumpage regulation will have to be justified on an individual basis.

3) Utilization standards - are essentially the same as for normal stands although field enforcement has been relaxed in the aspect that licensees will only be required to utilize attacked logs that are capable of making 50 percent of the soundwood volume into lumber.

It would have been nice if all of the noted considerations had been clearcut decisions. However, all deliberations had to be tempered by other factors which varied in time and place. Some of these factors were:

- market conditions, including economics of logging;
- mill requirements - that is, smallwood/largewood ratio;
- strategies with the least adverse impact on the environment and fish and wildlife;
- the harvesting of grey attacked stands before they become completely uneconomical to harvest;
- licensee requirements for a balance of summer and winter shows;
- equipment availability such as cable systems, low ground pressure skidders.

That basically covers the policies and strategy for the spruce beetle attack.

At present, the mountain pine beetle, with a few exceptions, does not exist in the Prince George forest region other than as a naturally occurring endemic population. To the south, in the Cariboo forest region there exists a large epidemic population covering approximately 400,000 hectares. This population is

active and expanding northward, thereby presenting a serious risk to the 131,000,000m^3 of susceptible pine in the Prince George timber supply area bordering the Cariboo region. The susceptible pine at risk, in the total Prince George timber supply area, amounts to approximately 286,000,000m^3.

Given this potential expansion, we are in the process of formulating a strategy for managing the mountain pine beetle in the timber supply area. Our proposed strategy to date is as follows:

1) Where attack is detected close to access but not in an existing development plan:

   a) Probe infestation to determine size of population and point in life cycle. In freshly attacked areas of less than one hectare one of the following options should be undertaken:

      i) If host trees are within three weeks of initial attack, hack and squirt with a lethal chemical;
      ii) If attack is older than three weeks, fell and burn.

   b) If the extent of the attack does not allow for single tree disposal, the area should be incorporated into the plans of one of the established operators and scheduled for harvesting. Infested trees should be segregated if necessary to ensure the logs are processed through a mill at the earliest possible time and the site treated to ensure any insects contained in the stumps are killed.

2) If attack is detected within an approved development plan, the established licensee should be requested to amend the plan to schedule the harvesting and treatment of the site at the earliest possible time.

3) If attack is not located close to access or not in a development plan, the area should be probed to determine if manual treatment is adequate to deal with the problem. If not, then a strategy of concentrating the population with pheromones should be considered until such time as access can be developed to allow for the harvesting and treatment of the area.

4) There should be no hauling of beetle infested logs during the flight period.

The ministry is also working on the development of an access plan for the area adjacent to the Cariboo region and is determining what allowable annual cut is available should any epidemic develop.

In summary, the harvesting strategy developed must take into consideration.

- The extent of the attack,
- how quickly the attacked timber can or should be harvested,
- how much allowable annual cut is available,
- how to deal with any accelerated cut, and
- the question of access.

BEETLE-KILLED PINE PROCESSING PROBLEMS AND OPPORTUNITIES: A BRITISH COLUMBIA PERSPECTIVE

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This paper is based on a study carried out at Forintek's Western Laboratory (Nielson and Wright, 1984).

The study was initiated at the request of the Canadian Forestry Service, in support of a Canada-U.S. Agreement on Lodgepole Pine/ Mountain Pine Beetle.

The overall purpose of the study was to review the processing of mountain pine beetle-killed lodgepole pine in various forest products operations; to examine the particular problems this presents, and determine further work that might be carried out to help alleviate any of the problems identified. The study concentrated on sawmilling, but also covered veneer and plywood, pulp, particle-board, and treated wood products manufacturing.

Literature was reviewed and a survey made of milling operations in the Cariboo region that were salvaging and processing beetle-killed timber.

BACKGROUND

Figures 1 and 2 illustrate the magnitude of the mountain pine beetle problem in British Columbia.

In 1983, the most recent year for which data are available, the beetles attacked trees over 482,300 hectares, killing trees with a total estimated volume of 12,194 thousand cubic meters. In the same year the lodgepole pine harvest totalled 16,894 thousand cubic meters. In two of the past three years the volume of lodgepole pine killed by the mountain pine beetle has exceeded the lodgepole pine harvest in B.C.

The current series of epidemics began in the early 1970's in the southeast of B.C. They peaked there in the late 1970's, and have since declined, reportedly due both to depletion of susceptible host and to harvesting operations.

Infestations in the Cariboo Forest Region have risen dramatically in recent years and this has been by far the most severely affected area up to the present time, where the area under attack is approximately 15 times the area of all species harvested annually.

The Prince George Forest Region has been the least affected region to date; but with the beetle moving north, and approximately 25 percent of the mature timber volume in the region being lodgepole pine, there is obviously no reason for complacency.

PROGRESS OF A MOUNTAIN PINE BEETLE ATTACK

It is useful to review the sequence of events involved in a mountain pine beetle attack and precisely how the results of such an attack affect the utilization of the tree.

The mountain pine beetles infest living lodgepole pine trees around mid-July and August. The beetles prefer the larger diameter trees, and major outbreaks usually only develop in stands over 80 years old, with many stems over 25 cm in diameter. An outbreak can last from four to 18 years with progressively more stems killed each year. Hence, an area under attack will contain varying proportions of trees killed at different times, dying trees, and green unattacked trees.

Blue-stain fungi are carried into the trees by the beetles and within a few weeks begin to cause staining of the sapwood. The fungi are spread by the beetles within the galleries, and later by larval mining around the tree. Tree mortality only becomes readily noticeable by the following spring or summer with the appearance of yellow and reddish-brown foliage.

EFFECTS ON BOLE AND WOOD CHARACTERISTICS

The death of the tree has three main effects on the wood and bole which affect its use in solid wood products:

1. rapid moisture loss from the sapwood,
2. development of blue-stain in the sapwood,
3. development of checks and splits as the wood dries below the fiber saturation point.

Moisture Loss:

The effect of mountain pine beetle on wood moisture content of successfully attacked lodgepole pine trees has been well documented in a study by Reid (1961).

Outer sapwood, which normally is 85-165 percent m.c. (o.d. basis) in the standing tree, quickly loses moisture after trees are successfully infested. For trees attacked in July, the outer sapwood m.c. dropped to about 40 percent by the end of August, and within one year of attack it was down to fiber saturation point, below which shrinkage in the wood will occur (Figure 3).

Blue Stain:

The blue-stain begins to spread shortly after successful attack of the tree and eventually invades most of the sapwood. Again, an illustration from Reid, 1961, (Figure 4) shows how the development of blue stain in the sapwood parallels the development of the insect brood in the tree and the loss of moisture in the sapwood.

Checking and Splitting:

Checking and splitting begins the year after attack as the outer sapwood dries below fiber saturation point, and continues over the next few years as foliage is lost and the bark becomes loose and falls off.

All of the problems in processing this material in solid wood products plants are attributable to these three factors:

- low moisture content,
- blue-stain, and
- splits in the bole.

All these factors relate to the drying out of the bole.

If our processing problems with this raw material are mainly attributable to drying of the stem over time, we can do two obvious things to minimize the problems:

1. harvest the material quickly, and
2. keep the material wet.

These actions will inhibit both loss of moisture below fiber saturation point and splitting of the bole.

However, once a tree is successfully attacked nothing can prevent the blue-stain from developing.

It is generally recognized that the strength of wood is not significantly reduced by blue-stain. The exception is in toughness, where the reduction may be as much as 25 percent or more. This may well contribute to some of the losses that occur during the processing of this material, particularly breakage due to impact, which is also partly attributable to the dry wood condition.

COMPOSITION BOARD PRODUCTS

The use of dead lodgepole pine timber has been investigated for various wood composite panel products including hardboard, particle board, medium density fiberboard, and waferboard (Maloney, 1979; Maloney et al., 1976).

Results of these studies indicate that dead timber is suitable for the manufacture of all these products, with the exception of waferboard, in which there are significant problems in cutting acceptable wafers from dead timber.

For the other board products, loss of bark in older dead trees was considered an advantage, as was the low moisture content, which would reduce drying costs.

In British Columbia there are few such plants, and any new ones would likely use cheaper available supplies of wood residues, as is the practice in existing plants.

TREATED WOOD PRODUCTS

Available information on preservative treating of dead lodgepole (Lowery and Host, 1979; Tegethoff et al., 1977) indicates that the treatability of this material is enhanced due to three factors:

1. increased permeability due to blue-stain fungi,
2. the dry wood condition, and
3. checks and splits in the bole.

Treating schedules must be shortened accordingly to prevent excessive chemical uptake. A further advantage of using this material is the elimination of the need for long yard seasoning periods, and the associated costs of holding large inventories.

UTILIZATION ALTERNATIVES - B.C. PERSPECTIVE

While there appears to be a good marriage between dead timber and composite board and treated wood products, this will do little to use up the vast supplies of dead timber available, since wood consumption for these products in B.C. is relatively minor. The forest industry in the B.C. Interior is mainly comprised of softwood sawmills, several veneer and plywood plants, and several pulp mills. The pulp mills are virtually totally dependent on residual chips from the sawmill and veneer and plywood sectors.

It is apparent that current salvage and use of beetle-killed pine must rely heavily on the ability of sawmills, and to a lesser extent, veneer and plywood operations, to process this source of roundwood.

What we can achieve through these options will dictate the extent to which beetle-killed timber can be processed in British Columbia, both for the time being and in the foreseeable future.

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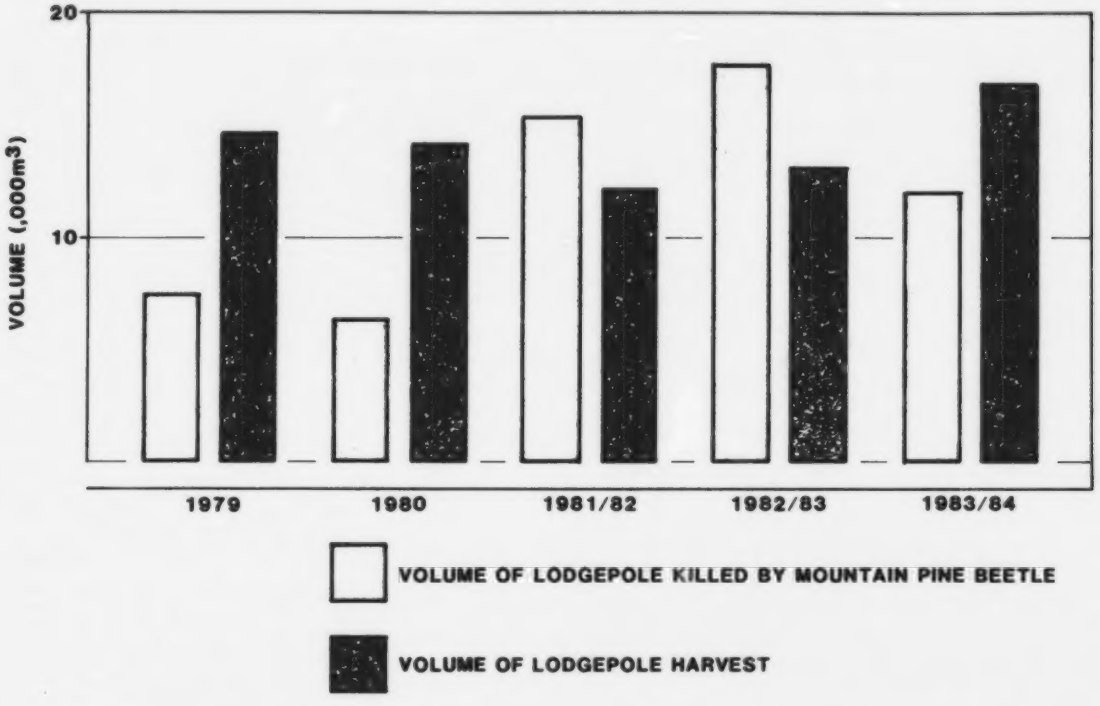

Figure 1. Comparison of lodgepole pine harvested and volume killed by bark beetles in B.C.

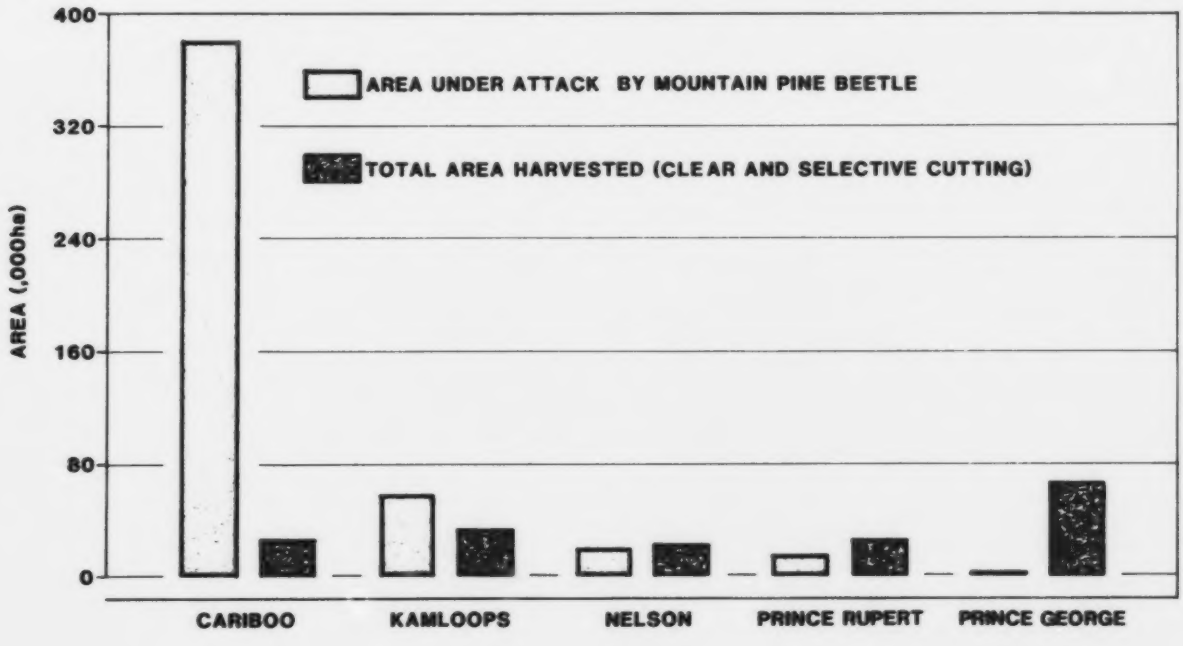

Figure 2. Comparison of total area harvested and area under attack by mountain pine beetle, 1983/84.

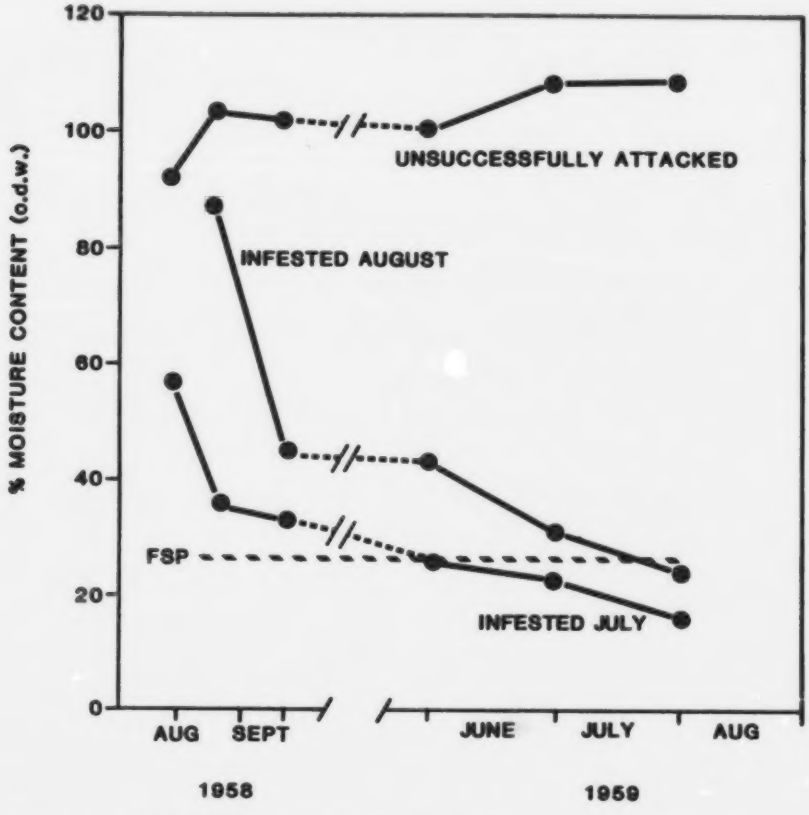

Figure 3. Outer sapwood moisture content of successfully and unsuccessfully infested lodgepole pine at 3 1/2 feet above ground.

Source: Reid, 1961.

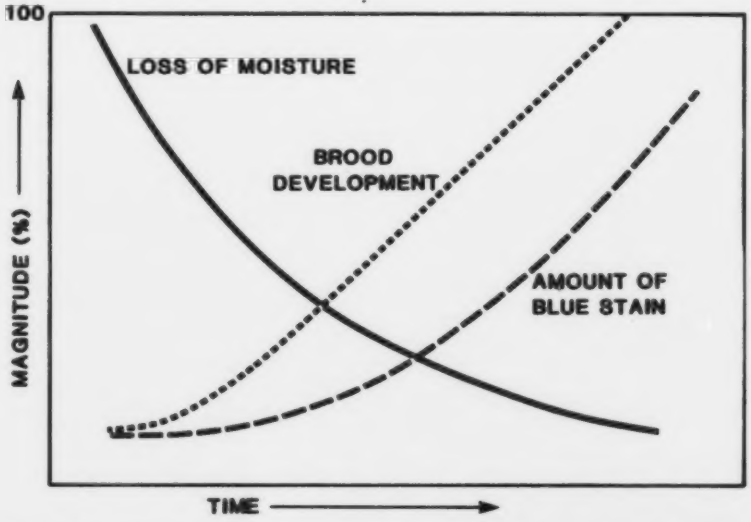

Figure 4. Diagrammatic illustration of blue-stain penetration, loss of sapwood moisture, and degree of brood development within infested lodgepole pine.

Source: Reid, 1961.

SALVAGE AND STORAGE OF BEETLE-KILLED TIMBER

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SUMMARY

Salvage of beetle-killed timber can reduce the loss of timber by the forest industry. Protection of logs from wood destroying insects and fungi, after initial attack has occurred, will increase the period over which the resource may be converted to marketable products.

Moisture, oxygen and temperature are the factors which determine the rate and extent of physical and biological deterioration of wood. Control of one or more of these factors is required for effective long-term storage.

Reduction of moisture content below fibre saturation point will help preserve wood from fungal attack. This process is expedited if bark is removed either mechanically, or as an affect of beetle or fire activity. Lumber production from beetle-killed spruce, showing heavy weather checking, gave 82 percent of normal recovery and 72 percent of lumber value, 20 years after initial attack.

Temperature control has limited application but may be utilized at higher elevations where snow accumulations remain until early summer.

Water spraying or water storage shows the most promise for long-term storage on an operational scale. Water spraying must be complete but may be intermittent. Studies indicate that cost of mill yard spraying may be only a fraction of the benefit received ($0.20/Mfbm cf $6 - 18 Mfbm benefit). Water storage has been effective in reducing log deterioration, as demonstrated in a large scale project initiated after a forest fire in Australia. Environmental concerns associated with water storage must be considered.

If the beetle-killed pine and spruce resource of British Columbia is to be utilized to the greatest advantage, industry, government and research organizations must cooperate with efforts to develop long-term storage strategies for the resource.

INTRODUCTION

Long-term storage of beetle-killed timber, combined with effective, inexpensive control of wood destroying fungi, could lessen the effects of the resource crisis facing interior mills today.

Industries who rely on natural resources for supply of raw material periodically are faced with dramatic changes in the availability or quality of the raw material. The industry is usually in no better position to accommodate or accept these dramatic changes than their customers are to accept a change in the product supplied. The occurrence of these changes may be gradual with time or very sudden, and may be short-lived or permanent. If the change is both gradual and short-lived, the effect on the industry, and more important, the customer may be slight--even to the extent of being undetectable. A very sudden, permanent change, however, may have drastic effects. The survival of industry would rely on its ability to adapt to the new conditions economically, and to develop an effective marketing strategy to change customer expectations or find new customers.

The interior forest industry has been faced with a potentially serious change in raw material supply due to beetle infestations during the last 15 years. Most mills have addressed the problem to some degree; some have attempted to document and evaluate the effects on their operations. Hopes that the problem would remain minor and short lived, however, can now be viewed as past dreams and the reality facing the industry, especially in some regions, is a long-term change in raw material supply to beetle-killed timber.

The widespread destruction of a large portion of the resource base will mean the reduction of future wood supply, and harvesting of stands having higher utilization risk, smaller diameter (second growth stands), lower per hectare volumes and undesirable species mix. Anything that can be done to extend the period over which killed timber may be utilized should receive widespread and careful attention.

WOOD DETERIORATION PROBLEM

Wood deterioration results from physical and biological actions, usually in some combination, and often more than one of each type. In the case of beetle or fire-killed timber, the initial attack has taken place and storage efforts must be focussed on reducing the rate of deterioration and inhibiting the occurrence of additional wood-destroying mechanisms. The raw material can not be returned to its original state, but the rate of deterioration may be reduced to allow more of the affected resource to be utilized.

Weathering effects on killed or burnt timber will reduce the moisture content and cause surface checking of the wood. The rate of deterioration is influenced by temperature, direct sunlight, and the absence or retention of bark. With passage of time, surface checks will deepen to become major log splits, reducing recovery of lumber and plywood in both quality and quantity. If the deterioration is not compounded by the occurrence of rot, however, the raw material should remain sound and be useful for pulp and particle board or other composites. Mueller (1959) found that acceptable particle board could be produced from beetle-killed spruce which had been dead for 10 - 12 years in Colorado. All the bark had fallen off and there was no indication of any important effect on the value of the sound wood for particle board use. Lumber production, however, was reduced in total recovery (82 percent), grade distribution (74 percent Standard and Better cf 72 percent for a green tree sample), and lumber value (72 percent) (Cahill, 1980). This recovery experiment was carried out on wood, from the same insect attack, that had been dead for 20 years. Cahill observed that the loss was mainly due to weather checking which showed up as splits in the lumber.

Much more serious is the deterioration of wood by biological actions which alter the physical and chemical composition of wood beyond usefulness for any product. Once started, the deterioration of wood by wood-destroying fungi and bacteria is usually fast (within two years) and complete. The delay or prevention of initial attack is most important in long-term storage of logs. The conditions favorable to establishment and growth of fungi are suitable temperature, moisture and oxygen as well as food supply (logs). The latter cannot be controlled, thus prevention strategy must center on control of one or a combination of temperature, moisture and oxygen.

TEMPERATURE CONTROL

Temperature control will have only limited practical application for protecting wood against fungal attack. Some degree of success may be achieved by storing logs at higher elevations as long as snow and frost remain. Hauling schedules and coordination would have to be well managed. It may be possible to store a percentage of winter's logging production in snow areas until summer road conditions allow for road hauling to mill sites. Successful storage of frozen logs in the mill yard has been achieved by using mill waste (chips, sawdust, hog) as insulating cover for logs (Lane and Scheffer, 1960). This method is expensive because of material handling and waste disposal, as well as loss of residual revenue. The insulating property of sawdust and bark mulch, however, is well known and was effectively used for ice storage before the introduction of large refrigeration units.

MOISTURE CONTROL

Moisture content manipulation has received more attention than temperature control. Moisture content below 25 percent and above 65 percent (oven dry basis) is generally unsuitable for most decay fungi. The study, cited above, on Engelmann spruce (Picea engelmanni Parry) in Colorado showed that the harsh climate, cold weather followed by dry summers, reduced the trees' moisture content, thus preventing the establishment of fungal growth, but showed an increase in loss (39 percent in value) due mainly to weather checking (Aho and Cahill, 1964). Bark removal appears to be a prerequisite for effective control via moisture content.

Studies in the Maritimes on open storage of budworm-attacked balsam fir (Abies balsamea (L.) Mill) and spruce (Picea spp.) logs in piles gave satisfactory results for barked logs (Unligil, 1984). In Cape Breton Island, log piles of freshly harvested material (budworm-attacked) were established yearly between 1977 and 1980. One 1978 pile was debarked, using mobile equipment, in mid-1979. Logs were removed in July 1980, August 1981 and June 1982 and examined for moisture content (sapwood and heartwood) and fungal deterioration. Results showed favorable moisture content for fungal deterioration in unbarked logs but levels below or at fiber saturation point for barked logs (Table 1). Occurrence of advanced and incipient decay was much higher for unbarked logs. Unligil concluded that storing unbarked roundwood outdoors caused deterioration of the wood, to a state unsuitable as forest product raw material, in two to three years. Debarking of logs, at the beginning of storage, resulted in much lower rates of deterioration and satisfactory storage of at least four years.

A similar experiment was established for spruce logs at Fredericton, N.B. Normal, defoliated and dead trees were sampled. Logs stored with bark on, remained at moisture content levels which favored fungal growth. Moisture content for logs without bark decreased to values generally known to be at or below the lower limit of moisture content range favoring fungal growth (Table 2).

Conclusions were that logs cut from normal, defoliated and dead (standing) trees deteriorated within two years if unbarked. The deterioration was much more advanced after three years. On logs of the same region, but stored with bark removed, the deterioration was negligible after two years and still insignificant after three years.

OXYGEN CONTROL

Water Spraying

Water spraying of log inventory in mill yards has been effectively used as fire and ambrosia protection, as well as to check biological deterioration of stored logs (Dobie, 1965). Water keeps the moisture content above the point favorable for fungal growth and also acts as an oxygen barrier. Water coverage must be complete, especially to reduce end checking of logs which could create channels for fungal attack, as well as cause reduction and degrade of lumber recovery.

Use of water spraying requires adequate drainage to prevent muddy conditions. Pollution considerations must also be evaluated and considered. Dobie estimated that between 100 and 200 litres of water per minute per thousand cubic metres of logs is required for adequate protection. Duration, frequency and cycles required for effective spraying, however, varies among authors.

Roff and Dobie (1968) reported two experiments (Williams Lake and Prince George) on water spraying of pine and spruce logs to check fungal deterioration. Lodgepole pine (Pinus contorta Dougl. var latifolia Engelm.) and white spruce (Picea glauca (Moench) Voss) logs were stored in two mill yards at Williams Lake for six months (April to September). Species were piled separately and one pile of each species was water sprayed while the other was unsprinkled. Spraying occurred for 15 minutes per hour on a 24-hour basis. Water consumption was 1,000 litres per hour per pile. Lumber cut from sprayed pine was free from deterioration. In contrast more than half the studs cut from dry stored logs contained incipient decay. Veneer peeled from spruce logs showed similar results between sprayed and unsprayed bolts.

In a similar study on white spruce, in the Prince George area, two piles of logs (60 cubic metres (m) each) were watered, one for 20 minutes per hour on a 24-hour basis, the second only during daylight hours at the same hourly schedule. A control pile was not watered. Spraying commenced in mid-April and continued until mid-October. After three months, sapstain was recorded in lumber from "day only" and unsprayed logs, although occurrence of stain was not sufficient to cause lumber degrade. After six months, "day only" spraying suffered the heaviest loss from decay but logs sprayed on a 24-hour schedule were entirely free of defects associated with storage. Unsprayed logs suffered heavy losses from grub holes which may have overshadowed the effect of decay. At today's prices, the loss in lumber recovery for unsprayed logs was $18.46/Mfbm and $6.71/Mfbm for logs sprayed during the day, $1.45/Mfbm of which was attributable to sap rot. In comparison, the cost of a sprinkler system to adequately cover a log yard containing six log decks 240 m long, 12 m wide and 6 m high and spaced 4 m apart (containing approximately 72.5 thousand cubic metres of logs) would be approximately $10,000. The cost, amortized over five years, would be $3,000/year or 15 to 20 cents per Mfbm.

A Swedish study (Svensson, 1962) on sprinkling pine logs showed no difference in degrade between logs sprinkled continuously during daylight hours and intermittent spraying (four minutes on, 12 minutes off) on a 12- or 24-hour basis. Considerable degrade was detected in unsprayed control logs. A U.S. study (Lane and Scheffer, 1960) showed that continuous or cyclical spraying significantly reduced the occurrence of stain and rot over the unsprayed

control. They also concluded that spraying does not have to commence until early summer. To ensure good results, however, spraying should be initiated by about mid-May in areas climatically similar to central Wisconsin. Intermittent cycles were satisfactory if spraying was frequent enough to keep logs ends and surfaces continuously wet.

Water Storage

Water storage is another method which has been used to successfully protect logs against fungal attack. Water storage is also effective at reducing the damage and survival rates of larvae already in the log (Gardiner, 1962). Experiments in Quebec on beetle-attacked pine and spruce logs showed a three to four percent survival rate of larvae (under bark) after at least a month of storage under water. If larvae were in the wood, survival was higher at 33 percent. Shorter storage and exposure above water also increased the percentage survival. Similar results were obtained from the examination of fire-killed and insect-attacked white pine logs water driven to a mill in northern Ontario. After at least a month in water, larval survival rate was four percent for submerged sections and 12 percent for sections above water.

A recent forest catastrophe in Australia, led to a large scale lake storage project and government/industry cooperation to prevent further losses. In February 1983 (late summer) a severe fire in a pine forest of South Australia destroyed over 19,000 hectares of plantation forest, much of which was prime quality multi-thinned plantation (40 years plus). The area accounted for 23 percent of the South Australian Woods and Forests Department forest estate.

Salvage operations started almost immediately. Woods and Forests doubled its mill production and another large firm cooperated to process as much material as possible before discoloration affected the wood quality. Within two months there was industry-wide cooperation for the long-term storage of logs and lumber to prevent a market flood of finished products. By October, 1.8 million m^3 of wood had been recovered, 700,000 m^3 of which had been converted to sawn products. That volume was equivalent to eight months wood supply for Australia's entire softwood industry.

The cooperation extended to Wood and Forests was quick, uncompromising and universal from small logging and sawmill operators, to State and Federal government agencies. Manpower and equipment, for the logging effort, was recruited from logging contractors in Tasmania, New South Wales and Victoria. On the conversion side, South Australian and Victoria mills within reasonable hauling distance suspended cutting of green timber wherever possible, increased shifts, drying capacity and anti- sapstain spraying and dipping.

A plan to store bark-on logs under large scale spray installations was initiated. Four above-ground storage areas for 300,000 m^3 of logs were established. Water for the sprinkler system came from wells. In addition, Adelaide area mills planned to store 70,000 m^3 of logs under water spray--requiring 4.5 million litres of water daily. The water source was sewage treatment effluent which was normally used in Adelaide's irrigated vegetable growing areas.

The most novel idea, however, was to store 700,000 - 750,000 m^3 of logs under water in Lake Bonney. Located on coastal flats, Lake Bonney has a lake bed consisting of hard limestone and an average depth of two metres. Two causeways were constructed reaching 300 metres into the lake, to allow for off loading of logging trucks by front-end loaders. Logs were delivered at a rate of 1,200 loads per week or 40,000 m^3. Storage and processing of wood will continue for three to five years.

Water Storage Concerns

Large scale water storage of logs has been proven as an effective protection against wood destroying agents. The Australian example cited above, and the successful harvest of logs from Lake Williston in northern British Columbia following the hydro lake development project are two recent examples. This method, however, has recognized environmental concerns which require evaluation and consideration.

The oxygen supply in water can be seriously affected by water storage of logs (Eriksson, 1974). Logs on the water's surface will reduce the absorption of sunlight, which may change the balance of oxygen-producing photosynthesis processes by water plants. Bacterial activity due to wood or bark decomposition will further deplete the oxygen supply.

Increased incidence of bacterial attack on pine logs stored in stagnant ponds (due to anaerobic conditions) was reported by Ellwood and Ecklund (1959). The bacteria may cause brown-stain and increase the porosity of the wood which would increase the absorption of water-repellent preservatives used for treating lumber. This over-porosity causes subsequent difficulties in painting and finishing. An increase in permeability was also noted by Adoff et al. (1972) in spruce logs stored under water for three years in Europe. The specific gravity in the outer zone of wood decreased by 10 percent due to fungal activity. Lumber production was not reduced, however, because most of the affected volume was chipped in the conversion process.

Some environmental concerns can be reduced by pre-storage preparation and management considerations. The loss and problems associated with sinkers could be reduced by bundling. Major leaching, water discoloration and bacterial activity can be reduced if bark is removed prior to water storage (Graham and Schaumburg, 1969). Reduced storage time, by scheduling inventory turnover (especially if small storage ponds are employed), will reduce the risk of creating anaerobic conditions in the water.

CONCLUSIONS

Infestations of bark beetles in the past decade in British Columbia have resulted in wide- spread destruction of pine timber resource and regional mortality of spruce. Timber volume loss estimates in the Cariboo Forest District have increased dramatically, from 2.1 MM m^3 in 1981 to 13.6 MM m^3 in 1982 and 12.5 MM m^3 in 1983 (Nielson and Wright, 1984). Loss estimates for 1984 and 1985 are expected to remain high. The ability of the forest industry to match the infestation rate by salvaging the attacked timber is hampered by accessibility, mill production capacity and market constraints. Short to medium term estimates indicate a large resource of "standing dead" timber.

The impact on the forest industry of a beetle-killed pine and spruce timber resource will remain a concern for many years. Government, industry and research organizations should cooperate in an effort to find solutions to the short-term salvage and utilization of the affected resource, and long-term timber shortage which will result from these disasters. The determined effort and cooperation exhibited by the Australian forest industry and governments supplies a model for the management and utilization of timber resources affected by natural or man-caused disasters.

Long-term storage strategies for beetle-killed timber must be developed if this resource is to be utilized to the greatest advantage. Water storage and log deck spraying are two methods worthy of consideration for practicality and cost-benefits.

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Table 1

Moisture and Decay Content of Balsam Fir on Cape Breton Island

	Percent				
	Year of Pile				
	1977 S/H**	1978 S/H	1978* S/H	1979 S/H	1980 S/H
Moisture 1980	81/50	61/69	22/25	78/52	81/58
Moisture 1982	91/43	77/58	33/45	88/73	50/53
Decay 1980					
Advanced	21/3	5/8	1/10	4/4	Trace/Trace
Incipient	17/8	16/6	4/10	19/2	15/2
Blue Stain	2	2	1	1	1
Decay 1982					
Advanced	31/6	34/8	1/10	20/7	19/8
Incipient	14/2	10/4	5/6	13/4	9/Trace
Blue Stain	1	1	1	1	2

*Barked
**S/H - sapwood/heartwood

Source: Unligil, 1984.

Table 2

Moisture and Decay Content of Spruce Logs in Fredericton

	Year	Moisture Content (%)		Fungal Activity(%)		
		Sapwood	Heartwood	Advanced	Incipient	Blue Stain
Normal						
with bark	1979	147.8	35.9	0	0	0
	1981	92.7	71.9	1	10	Trace
	1982	82.6	44.1	33	17	0
without bark	1981	28.0	30.6	0	1	Trace
	1982	18.6	20.2	Trace	2	0
Defoliated						
with bark	1979	137.2	41.8	2	2	Trace
	1981	71.9	52.0	1	14	1
	1982	58.3	35.7	37	18	0
without bark	1981	31.4	26.2	Trace	3	1
	1982	18.3	20.5	3	5	0
Dead						
with bark	1979	88.3	33.5	5	11	12
	1981	56.5	37.2	12	13	1
	1982	40.3	33.4	25	12	0
without bark	1981	29.6	25.0	1	8	1
	1982	18.4	20.3	4	8	0

Source: Unligil, 1984.

HARVESTING AND PROCESSING OF BEETLE-KILLED PINE

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INTRODUCTION

The attack of our timber resource by bark beetles, and associated biological agents, has resulted in protection measures, salvage operations, and discussion of storage techniques to ensure protection and utilization of the affected resource. The effort to improve the utilization of beetle-killed timber cannot stop at the mill log storage yard or the infeed deck. In 1983, Forintek surveyed 15 interior mill operations to discuss and note the problems experienced in sawmilling beetle-killed pine (Nielson and Wright, 1984). This paper summarizes the problems cited at these operations as well as pertinent information from the literature.

PROCESSING OF BEETLE-KILLED PINE IN A SAWMILL

Log Handling

The low moisture content of beetle-killed logs, sometimes below fiber saturation point, results in higher log breakage and damage during mill yard handling and debarking operations. Additional expenses will be incurred if debris has to be removed from the mill yard. If mixed green and dry logs are processed through the barker, the higher barker head pressure required for green logs will tend to remove excess wood from the dry logs. This will result in lower lumber recovery and increased downgrade of lumber.

Two indirect effects of processing increased amounts of beetle-killed timber are the increase in fire risk in the mill yard, resulting in higher insurance premiums, and the validity of weight and conversion factors where weight scaling is practised. Both may result in additional operating or overhead expenses.

Cutting Tools

Dry logs, with splits and bark-free areas, may pick up dirt and stones during the logging and mill yard handling processes. The dirt and stones are difficult to remove during the debarking process and rapid dulling of, or damage to, saw teeth will result during sawing. Overheating of saws and loss of saw stability may result when cutting dry wood, especially if saws are set up for cutting frozen wood.

Carbide tipping is as effective as stellite for cutting dry wood because the corrosive action of green wood (which affects carbide tips) is reduced or eliminated.

Generally, processing beetle-killed logs has only minor effects on cutting tools except for the increased occurrence of dirt in the logs (E. Kirbach, personal communication).

Lumber Recovery and Grade Yield

Study results show that grade yield is reduced more than lumber recovery when consuming beetle-killed logs. The losses also increase quickly with years since attack, with recovery losses exceeding 10 percent, grade losses (#2 and Better grade) of 25 percent, and value losses of 20 percent after five or more years since initial attack.

Spiral checking of stems seriously reduces the lumber recovery, while loss of wood during barking (previously mentioned) and additional breakage at chipping canter breakdown centers also add to lumber recovery loss. A drop in average log diameter, due to salvage operations of affected stands, has been experienced by some mill operators. This results in a lower overall mill recovery factor. Other operations, in contrast, have experienced an increase in average log diameter for the same reason. Generally, mills cutting beetle-killed pine report increased chip production (as expected with lower LRF) and increased trim loss due to log checking and splitting.

An increase in lower grade lumber, poor general lumber appearance, and the occurrence of blue stain all result in reduced lumber value and marketability, especially in present competitive and low demand market situations.

A study to quantify recovery and grade loss, conducted in southern British Columbia (Dobie and Wright, 1978), showed little loss in recovery or value in trees retaining dead foliage for up to two years (red top phase). For up to four years after attack, while trees retained tight bark, lumber recovery dropped significantly . Grade yield losses were seriously affected only after the "gray, loose bark" stage of deterioration was reached. Results of this study are shown in Table 1.

The economic effects of these losses are summarized in Table 2. The drop in lumber and total value was 10 percent after approximately four years following initial attack. Value dropped an additional 10-12 percent when the "loose bark" stage was reached.

Table 3 summarizes the effects of spruce bark beetle-killed timber for an interior sawmill operation (anonymous). The results were for a one-shift test comparison of green timber and logs which had been dead an average of two years. Recovery and value loss are similar to results quoted in the literature at 10 and 20 percent respectively. The drop in grade recovery is higher at 43 percent and the loss of export grade lumber reflects the occurrence of blue stain. Other observations include a 27 percent reduction in chip recovery, attributable to barker damage, but no reduction in chip quality. A high dust content was also experienced in the mill during beetle-killed log runs. Results of a Forintek study on lumber recovery and grade outturn for eastern spruce trees attacked by budworm are summarized in Table 4 (Forintek Canada Corp., 1980).

Losses increased after tree death and were augmented by the occurrence of fungal decay after tree death. A total value loss of 21 percent was estimated if the effects of lost recovery were added to the lumber degrade loss. Lumber grader training, to teach graders to recognize insect-caused defects, is important. At one mill taking part in the Forintek study, grader misjudgment of insect defect resulted in more grading discrepancies (and value loss) than actual degrade due to insect attack. The grader naturally anticipated more defect when working with affected lumber and biased his judgement towards overgrading.

Finishing

Drying and planing problems associated with beetle-killed lumber result from the uneven moisture content of the lumber before and after drying. Research to develop in-line moisture meters is in progress. Drying beetle-killed lumber separately, under reduced schedules, is required to reduce the lumber

degrade due to overdrying, planer breakage, and trim loss associated with beetle-killed lumber.

Marketing

Beetle-killed lumber is difficult to market overseas and in today's competitive market. Although blue stain does not affect the lumber strength or grade, acceptance is restricted for export grade. Wormholes will also restrict lumber to export markets. Oversupply/low demand market conditions result in greater customer sensitivity to product quality. One possible solution to enhance the marketability of beetle-killed lumber is machine stress rating (MSR) grading for a value-added project.

CONCLUSIONS

Interior sawmill operations will continue to process beetle-killed timber for many years to come. Efforts to contain the extent of attack have had limited success. Accelerated cutting of affected timber resource is presently being proposed in at least one forest district. Long term storage of logs, using underwater storage or water spraying techniques, have been suggested. Conversion of the resource will result in lower product recovery and value in sawmill operations compared with normal green log mix.

Changes in mill operating practices can help offset some these anticipated losses. Presorting of beetle-killed logs can help reduce losses during barking, drying, and planing by adjusting these operations to handle dry wood. Product diversification, such as production of ties and mine timbers may create new markets for beetle-killed timber. Machine stress rating of lumber has value-added potential.

All of these potential solutions have additional costs associated with them, but so do the losses incurred with reduced lumber recovery, product value, and production loss.

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Table 1

The Effect of Mountain Pine Beetle Damage on Dimension Lumber Recovery and Grade Yields in Lodgepole Pine

Time since attack or tree appearance	Lumber Recovery Factor fbm/m^3	Lumber Recovery Factor percent	Lumber Grade Yields (percent by grade) No.2 & Btr.	No.3	Econ.
Green Top	202	100	84	11	5
Red Top (1 - 2 years)	197	98	82	14	4
Gray Tight Bark (4+ years)	188	93	77	17	6
Gray Loose Bark (longer)	180	89	63	30	7

Table 2

Log Product Values for Beetle-Killed Pine Converted to Dimension Lumber and Pulp Chips - 1983

Tree Appearance	Lumber Values (percent)	Chip Yields (Metric tonnes/percent)	Total Value (percent)
Green Top	100	100	100
Red Top	95	104	93
Gray Tight Bark	90	109	91
Gray Loose Bark	79	113	82

Table 3

Effect of Spruce Bark Beetle
Attack on Recovery, Grade Outturn and Value

	Change (percent)
LRF (FBM/M^3)	-9
Percent Export	-11
Percent Domestic	12
Grade 2+	-43
#3	137
Econ.	76
Trim Loss Percent	40
Value ($/Mfbm) (1982)	down 15-20

Table 4

Budworm-Attacked Eastern Spruce
Recovery and Outturn Results

Timber category	LRF Reduction (percent)	Lumber Degrade (percent)	Product Value (percent)
Partially Defoliated	-2	-	-
Defoliated	-3	-2	-
Severely Defoliated	-3	-3	-1
Dead	-7	-40	-15

PROCESSING BEETLE-KILLED TIMBER INTO VENEER AND PLYWOOD

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Mr. Reiter's talk was largely based on a slide presentation which illustrated the difficulties in manufacturing veneer and plywood from spruce killed by bark beetles in the Prince George region. Since the visual materials have not been reproduced here, the following provides a summary of results of veneer peeling tests carried out at North Central Plywood (N.C.P.).

QUALITY IMPLICATIONS OF BEETLE-KILLED TIMBER

Following mortality of standing timber by bark beetles, a general scenario of wood degradation can be described. However, it must be remembered that the severity and length of time for the degradation to occur varies both from tree to tree and from one geographical area to another.

FIRST YEAR DEAD

Reduction in moisture content of the sapwood occurs rapidly because of the numerous holes bored through the bark, and exposure to the wind, causing extensive checking (cracking) along the entire length of the bole. In general, the higher the temperatures in the summer following attack and the greater the bark peeling by woodpeckers, the greater the depth of checking. Natural sloughing of bark is hastened when mortality is caused by beetle attack.

Additionally, subsequent attacks by secondary insects such as ambrosia beetles and wood-boring beetles cause further defects and/or infection by sapwood decay fungi (primarily Fomes pinicola).

Based on our study at North Central Plywood several years ago, it appears that the majority of blue-stain is lost during round-up and therefore has a minimal impact on veneer/plywood production.

SECOND YEAR DEAD

Depth of checking increases as further moisture is removed from the tree. Data taken from our operations east of Prince George showed the following rate of checking:

Years since death	Average Depth (cm)	Range (cm)
1	2.5	0.8 - 4.0
2	3.5	1.5 - 5.3
3	4.7	1.8 - 10.1

Rate of penetration by sapwood decay fungi is extremely variable from tree-to-tree but obviously is an important concern due to the substantial volume of wood in the outside shell of the tree which is excluded from the manufacture of wood products. Sapwood decay has been observed at depths of 2 to 10 cm in 2(+)-year-old dead spruce.

THREE OR MORE YEARS DEAD

Due to the difficulty in accurately determining the number of years since attack after the needles have fallen from the trees, we do not have much data on this type of material. However, some general conclusions can be drawn:

1. the majority of checking will have occurred by year three;
2. sapwood decay will continue to penetrate into the tree, including the heartwood.

N.C.P. BEETLE-KILLED SPRUCE TEST RUN

Sample logs delivered to the N.C.P. yard were debarked and sorted by log quality. The rotten and checked logs were chipped, and the acceptable peeler blocks were conditioned and peeled. Block counts, chip trucks and weights, and veneer recovery were recorded throughout the process.

Chipper Block Breakdown (out of debarker):

	Number	Percent
Large Chipper Blocks (over 19")	436	38.6
Small Chipper Blocks (19" and under)	581	51.5
Peelers	112	9.9
TOTAL	1,129	100.0

Cubic Meter (m^3) Yard Scale:

Total volume (m^3) = 362.83 m^3

Total weight 188,850 Kg x 79.46 % (avg.% ØD)

= 150,060 ØD Kg

FALLDOWN AND WOOD FLOW

The total log sample weight (150,060 ØD Kg) entering the yard was allocated as follows:

	Weight	
	(percent)	(ØD Kg from density conversion)
Direct to chips & fines	77.9	116,901
Lathe	7.8	11,638
Burner (Sawdust, rot, hog, scaling loss)	14.3	21,521
	100.0	150,060

VENEER MILL (LATHE)

The 31.2 m^3 of blocks peeled at the veneer mill resulted in the following output:

Veneer	6,441	ØD Kg
Veneer chips	3,314	"
Veneer fines	288	"
Cores ($3.744m^3$ x 373 ØD Kg/m^3)	1,397	"
Spinouts ($.530m^3$ x 373 ØD Kg/m^3)	198	"
Total block volume	11,638	ØD Kg

The 6,441 ØD Kg of veneer produced represents 4.3 percent of the total weight of logs delivered to the log yard.

STUDMILL PROCESSING

The volume processed at the studmill was:

	Pieces		m^3		ØD Kg
Cores in	110	=	3.744	=	1,396
Spinouts in	2	=	.530	=	197
TOTAL	112	=	4.274	=	1,594

Product recovery was as follows:

Chips	509 ØD Kg	(31.9 percent of total)
Fines	408 "	(25.6 percent of total)
2 x 4's	677 "	(42.5 percent of total)
Total	1594 ØD Kg	

VENEER RECOVERY

Actual veneer recovered from the lathe was 44.6 percent of the total volume input (Table 1); 55.4 percent was downfall into chips, spinouts and cores; 9.4 percent of this downfall was from the green chain into chips (between veneer clipped and actual veneer recovered).

From the veneer breakdown in Table 1, it can be seen that the actual random recovered was 4.8 percent higher than random clipped. This higher random count was due to the falldown from the sheets clipped which went into random.

The very high fishtail falldown (103.8 percent) was largely due to the overall poor conditon of the ribbon and small pieces clipped (rot, checks, veneer breakage). This veneer was not useable and went into the chipper.

Product returns and production costs based on this test were as follows:

Total Production		Gross Return
Veneer @ $28.75	47.1 m/8	$ 1,354.13
2 x 4's (220 pcs) @ $128.00 Can/fbm	1,173 fbm	150.14
Chips @ $48.50/odt	112.1 odt	5,436.85
Fines	9.3 odt	0
TOTAL RETURN		$ 6,941.12
Test Run Cost:		
Debarking and Chipping		$ 2,042.92
Veneer Processing		291.55
Log Cost (@ $21.11/$m^3$)		7,659.34
TOTAL COST		$ 9,993.81
NET RETURN		($ 3,052.69)

Table 1

Veneer Production (Total Run 53 Min.)

Cubic meters (m^3) into lather		31.6
Actual veneer produced		47.1 m/8
Veneer clipped tally		52.0 m/8
Lathe recovery	44.6 percent	
Veneer recovery	90.6 percent	

Veneer Breakdown:

	Actual m/8	Percent	Clipper m/8	
Sheets	30.0	63.7	32.9	-2.9 m/8
Random	14.5	30.8	13.8	+ .7 m/8
Fish Tail	2.6	5.5	5.3	-2.7 m/8
TOTALS	47.1	100.0	52.0	-4.9 m/8

PROCESSING DEAD TIMBER INTO VENEER AND PLYWOOD

D.C. Walser
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Mr. Reiter has discussed the mill problems encountered when processing beetle-killed timber into veneer for plywood.

Similar problems occurred in a preliminary peeling study of beetle-killed western white spruce conducted at Forintek. The results of this study showed that the veneer blocks from three-year-dead trees were extremely dry with an average moisture content of 27.6 percent and contained numerous splits and checks. In addition, the sapwood in many blocks was completely rotten and broke up when peeled.

One objective of this study was to investigate the effect of knife bevel upon veneer quality. Two knife bevels were tested, 1-3/4 inch (21°) and 1-5/8 inch (23°). As shown in Table 1, the sharpest knife, the 1-3/4 inch bevel, peeled the smoothest and tightest (least lathe check depth) veneer. However, veneer roughness was greater than normal, with all of the veneer outside our 0.020 inch roughness depth tolerance limit. Also, veneer handling was difficult because of the dry brittle wood.

This preliminary study showed that lathe set-up must be very good and knives must be kept sharp and accurately adjusted to obtain useable veneer from beetle-killed woods. To accurately set a veneer lathe the use of good lathe instruments is a must. Typical lathe instruments for adjusting horizontal gap, vertical gap and knife pitch angle are shown in Figure 1.

Another area of concern when peeling beetle-killed veneer blocks is the type of lathe chucks used to grip the blocks and transmit peeling torque. Since the dry blocks are severely checked any further splitting by chuck imbedment can spell distaster.

Present day chucks are constructed with wedge-shaped lugs as shown in Figure 2. Unfortunately, the wedging action of the lugs splits the wood on penetration. These splits weaken the wood area where the chuck must grip and can result in the spin-out of a significant number of veneer blocks. Spin-out occurs when the grip of the chucks on the veneer block is lost and the chucks can no longer provide rotational torque for peeling, consequently the remainder of the block cannot be peeled.

In a recent study at a local mill, 10 percent of the veneer blocks processed resulted in spin-outs. These were not from beetle-killed trees but over three quarters of the spin-outs were caused by the chucks splitting the block ends. Average veneer block diameter at which the spin-outs occurred was eight inches. Approximately 15-1/2 lineal feet of 1/6 (0.166) inch veneer was lost from each spin-out block. With blocks from beetle-killed trees the problem is magnified and could double the spin-out rate.

Splitting can be reduced somewhat by using long slender wedge-shaped lugs. However, this approach is limited by the fact that the lugs must have sufficient strength and stiffness to transmit peeling torque and to prevent breakage by knots.

Forintek has developed a new lug for lathe chucks that eliminates splitting without sacrificing lug strength and stiffness. This new lug has a stepped profile that is designed to compress rather than split the wood as it is driven into the veneer block.

Dramatic proof of the stepped lug's effectiveness in eliminating splits is shown in Figure 3 where the impression in wood of a stepped lug is compared with that of a typical wedge-shaped lug. The stepped lug produced no splits in the wood, whereas the wedge-shaped lug caused severe splitting. Figures 4 and 5 show two types of stepped lug inner chucks developed by Forintek.

Forintek's stepped lug chucks are presently being used by several mills. A license to manufacture the new chucks has been granted to Durand-Raute Industries Ltd.

Veneer from beetle-killed timber has a tendency to split during clipping and drying. A recent Japanese development may substantially overcome this problem. The Meinan Arist-Lathe tenderizes or incises the veneer as it is being peeled. Incising is achieved by a spiked roller that introduces frequent micro-checks on the tight side of the veneer to increase flexibility. This results in reduced splitting and breakage during processing of the veneer ribbon.

Laboratory tests at Forintek using several incising methods confirm the benefits claimed by the Japanese.

Forintek has modified its laboratory lathe to accept a four-inch incising roller (Figure 6) and is assessing the commercial significance of this type of equipment. Design specifications for a new incising system suitable for North American production lines is being developed.

Some of the problems of thickness variation and roughness in beetle-killed veneer may be reduced by optimizing lathe knife pitch.

Knife pitch or kinfe angle is the angle betwen a line drawn from the knife edge through the centre of the spindles and the ground face of the veneer knife. This is shown schematically in Figure 7.

As diameter decreases during the peeling process, knife angle must constantly change to maintain uniform veneer thickness. On existing equipment this is done mechanically by the knife carriage, which is slung on trunion bearings and rides on pitch rails.

Because wood characteristics vary from block to block even within the same species and because optimum pitch angle varies with thickness of veneer being peeled, the pitch angle in current lathe systems is never optimized.

If knife angle is too great, the knife either 'dives' into the block or the core is pulled into the knife if core diameter is small. In either case, the knife starts to chatter, resulting in corrugated, rough veneer.

If the knife angle is too small, the force of peeling drives the knife away from the block, resulting in thick and thin veneer.

To maintain a correct knife angle at all times, Forintek has developed a system which uses knife deflection as an indication of knife angle adjustment. Sensitive transducers, mounted in the backing plate,

monitor knife deflections that occur during peeling. The transducers sense when the knife is at the wrong angle and then a signal is fed to a microprocessor which controls a servo motor in the lathe pitch control mechanism. With this system knife angle is constantly being optimized to suit the particular cutting conditions of each individual block.

Another development which promises to revolutionize plywood manufacture and may in fact ease the beetle-killed timber peeling problem is the spindleless veneer lathe.

This lathe uses a totally new concept for peeling veneer. It is not an improvement on conventional lathes, or a super new powered back-up roll. It has no spindles whatsoever. The veneer block is hydraulically clamped between three full-length driven rolls, as shown in Figure 8. The two lower rolls move upwards toward the fixed roll and knife as peeling progresses. This ensures that the block remains constant in its presentation to the angle of the knife.

The spindleless lathe was essentially designed to peel pulpwood sized logs into useable veneer. Blocks of 7-1/2 inch diameter can be peeled down to a two inch core.

The lathe automatically loads itself, it does not require a charger, back-up roll or feedworks for a knife carriage and is driven at a fixed peeling speed of 400 to 600 fpm. The only requirement is that the block be reasonably round to within 50 percent of its circumference. This is not a problem when re-running cores from a standard lathe but on rough logs it is necessary to round them up to the 50 percent requirement. To do this a round-up lathe was developed. The round-up lathe operates on exactly the same principle as the spindleless lathe. However, instead of three full-length drive rolls, two cogged wheels on each roll contact the log (Figure 9). Logs from 14 inches in diameter down to five inches in diamter can be handled at a rate of up to 16 per minute. As with the spindleless lathe, fixed speed AC motors provide the drive.

Charles Schmidt of Demco Manufacturing Inc. in Texas developed the spindleless lathe. Durand-Raute Industries Ltd. of New Westminster, B.C. developed the round-up lathe and have acquired the world rights for the manufacture and marketing of both the spindleless and round-up lathes.

Weldwood of Canada Ltd, Durand-Raute Inc. and Forintek Canada Corp. have joined forces to assess, and if necessary modify, this new lathe concept specifically for Canadian production. Forintek purchased the prototype lathe and Weldwood installed it in their Kent Avenue mill in Vancouver for testing.

Tests thus far have shown that the surface of veneer peeled on the spindleless lathe is significantly smoother than conventionally peeled softwood veneer. There is, however, slightly more variation in veneer thickness but modifications to the lathe should eliminate the problem in the near future.

In regard to peeling beetle-killed woods with the spindleless lathe, the smoother veneer would reduce the roughness problems and elimination of the lathe chucks prevents spin-outs and further splitting of the veneer blocks.

In conclusion, there are methods available to reduce some of the problems encountered when peeling beetle-killed woods and I hope more will arise in the future. To coin a phrase, "Necessity is the mother of invention," the necessity is here, lets get on with the inventions.

Table 1

The Effect of Knife Bevel on the Quality of 1/8-inch (0.135 inch) Veneer Peeled from Beetle-Killed (Three-Year-Dead) Western White Spruce

Knife Bevel	Block Conditioning	Block Section	Veneer Roughness Depth (0.001 in.)	Lathe Check Depth (%)	Veneer Thickness (0.001 in.)
1-3/4" (21°)	140°F (60°C) Hot water spray	Sap	23.0	36	136
		Heart	23.2	50	137
		Core	21.8	47	137
	Weighted average[1]		22.8	46	137
1-5/8" (23°)	140°F (60°C) Hot water spray	Sap	27.8	68	135
		Heart	23.8	65	136
		Core	23.6	71	134
	Weighted average[1]		24.8	67	135

[1]Developed by applying a weighting factor of two to heartwood and one to sap and corewood.

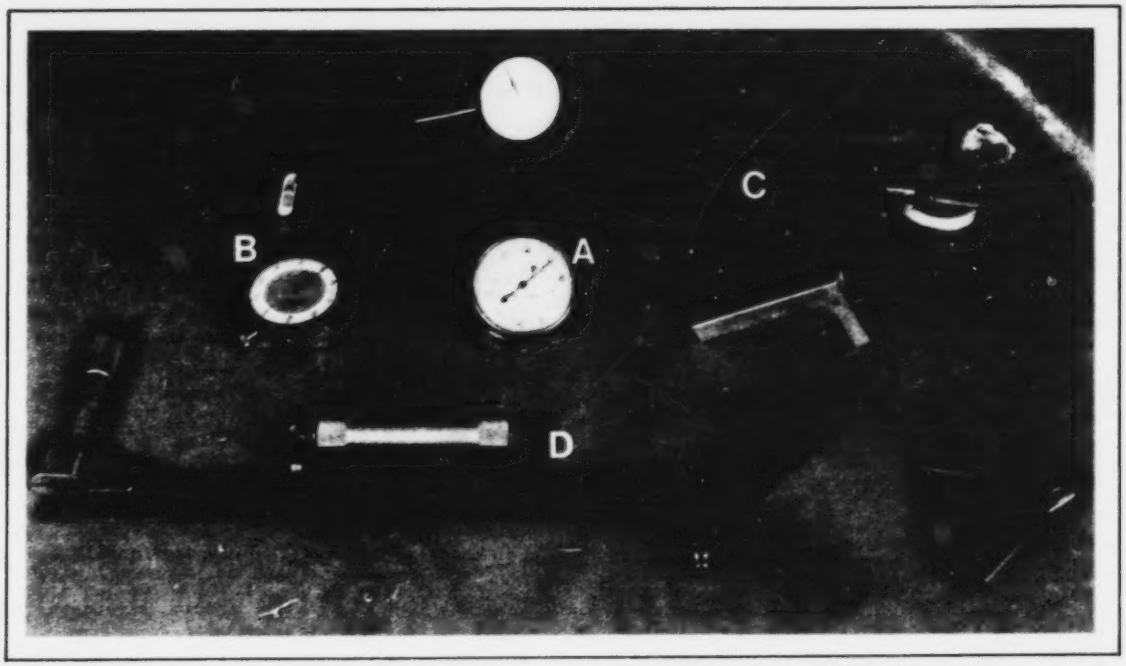

Figure 1. Lathe instruments: (A) Horizontal gap, (B) Vertical gap , (C) Knife pitch , (D) Knife Height.

Figure 2. Side view of the wedge shaped lugs used on commercial lathe chucks.

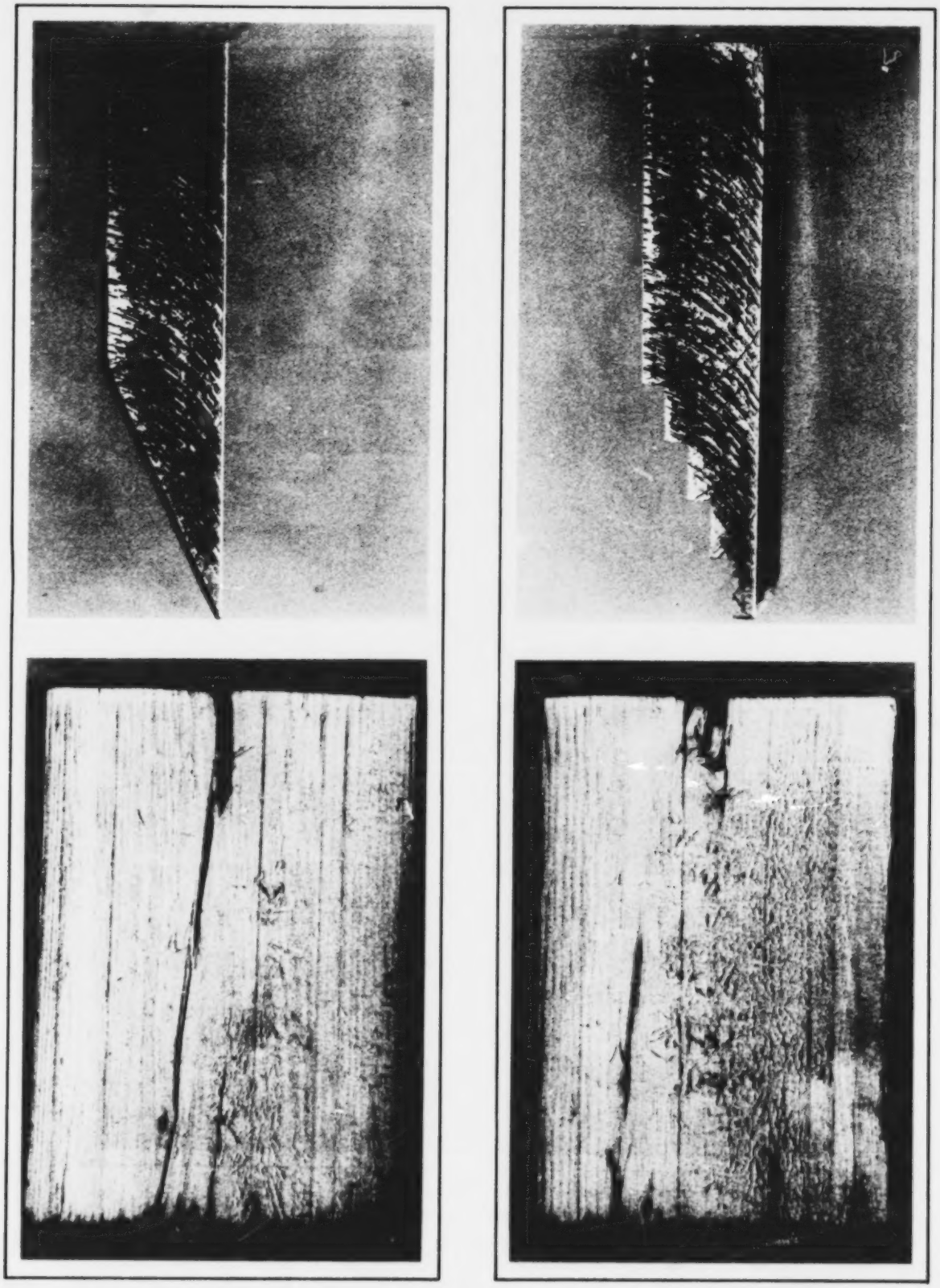

Figure 3. Chuck lug impressions: Left – Wedge lug Right – Forintek stepped lug.

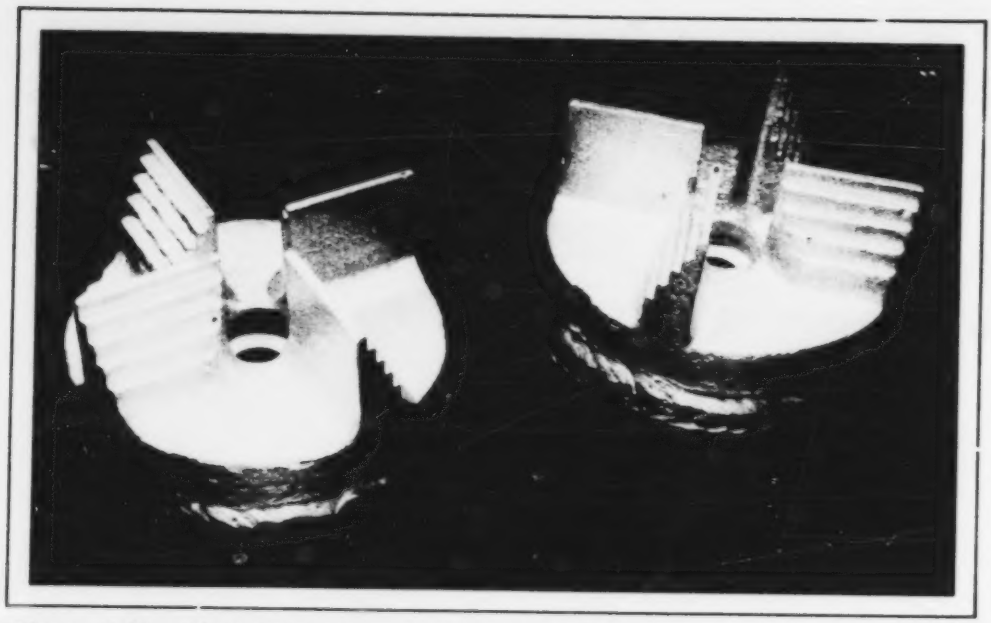

Figure 4. New Forintek chuck with four stepped lugs.

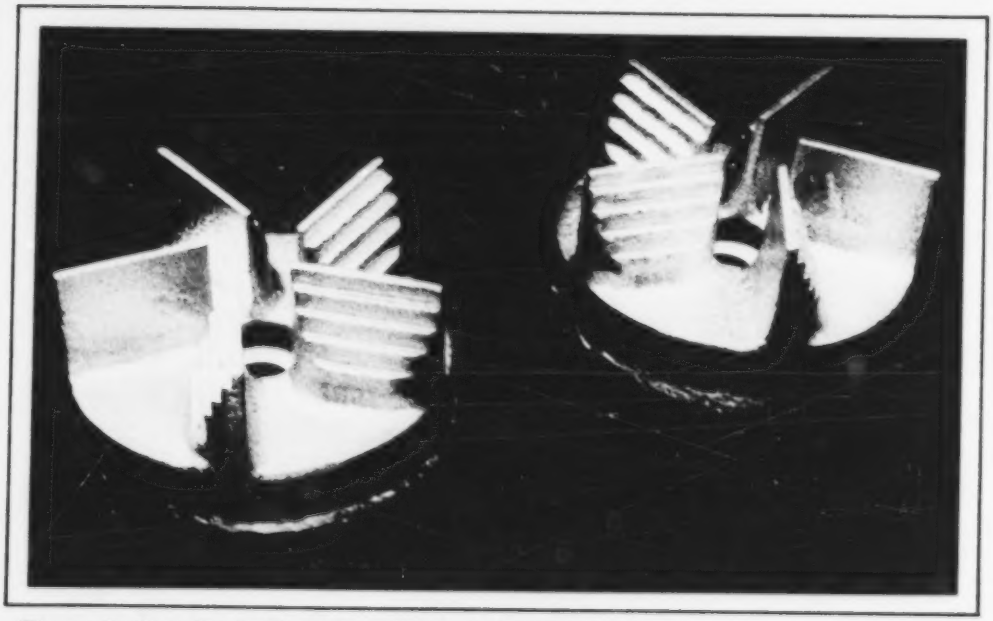

Figure 5. New Forintek chuck with five stepped lugs.

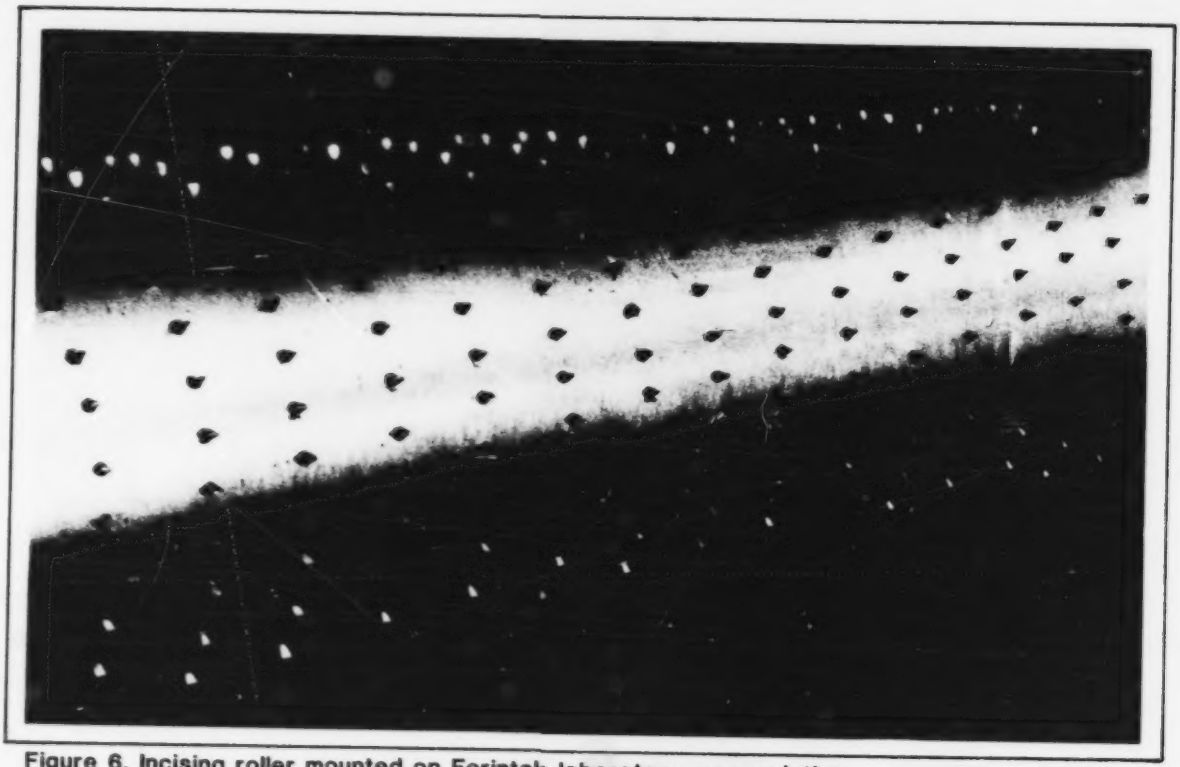

Figure 6. Incising roller mounted on Forintek laboratory veneer lathe.

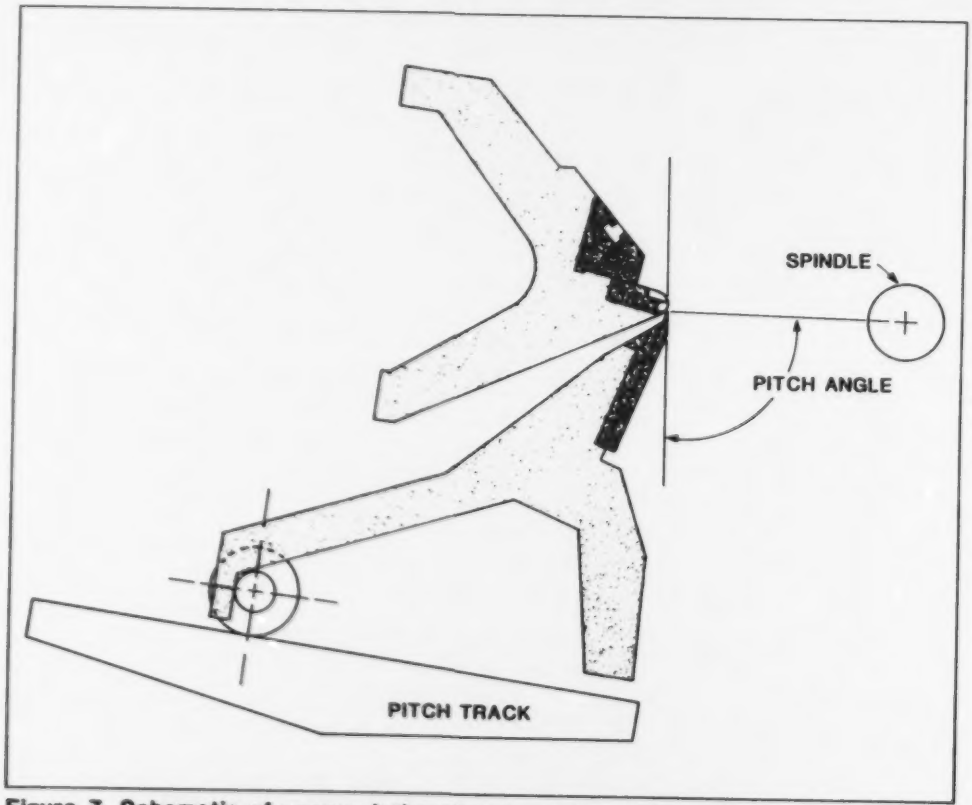

Figure 7. Schematic of veneer lathe showing knife pitch angle.

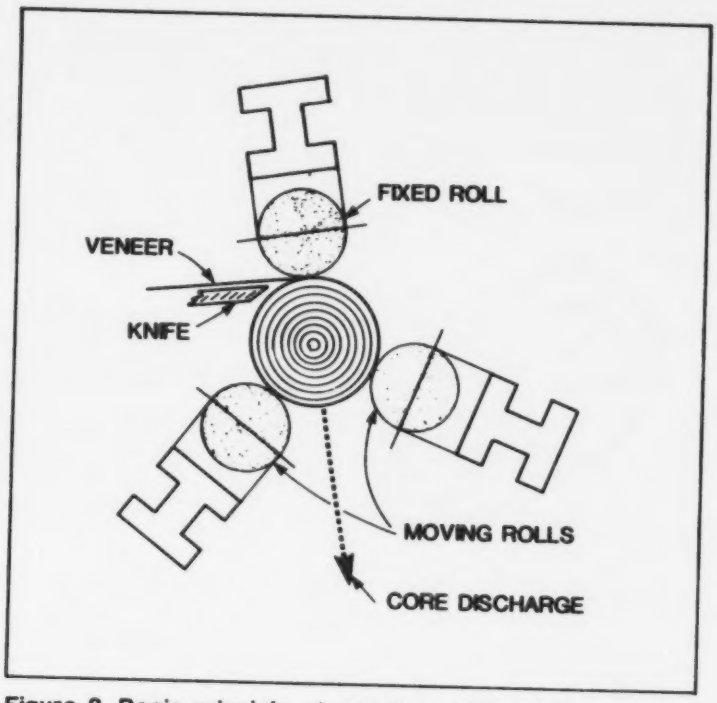

Figure 8. Basic principle of spindless lathe peeling.

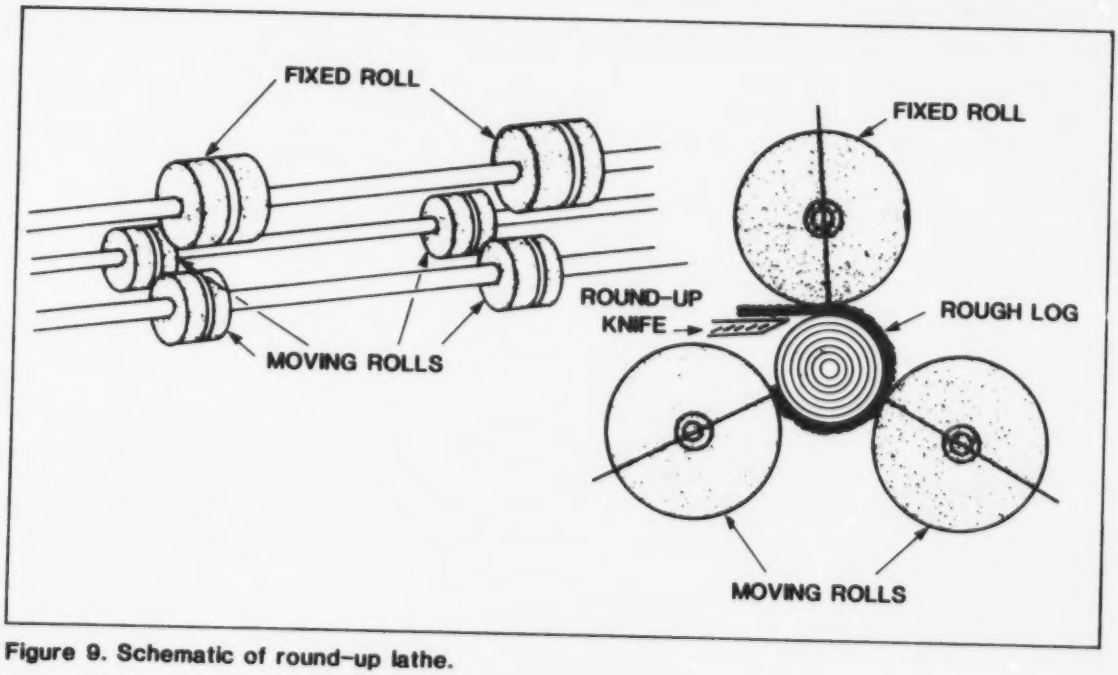

Figure 9. Schematic of round-up lathe.

VOLUME AND VALUE RECOVERY FROM LIVE AND DEAD LODGEPOLE PINE

Marlin E. Plank, Thomas A. Snellgrove and Thomas D. Fahey

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ABSTRACT

A brief discussion of the results of six studies is used to compare volume and value recovery among live, recent dead, and older dead lodgepole pine (Pinus contorta Dougl. ex Loud) in the western United States. Logs were processed into four major products: boards, random-length dimension, studs and veneer. Absolute values for the average-sized log (12 cubic feet) were highest for boards followed by dimension, veneer and studs. The percentage of decrease in value from live to dead, however, was least for studs and most for boards.

INTRODUCTION

In keeping with the theme of today's seminar, I am going to discuss volume and value recovery from live and dead lodgepole pine (Pinus contorta Doul. ex Loud.). I want to present some background information, briefly cover the methods used in the studies, discuss the results, and end with our conclusions. Keep in mind that this presentation is a synopsis of a compendium on recovery from live and dead lodgepole pine (Fahey and others in press) to be published this fall or winter.

The volume of merchantable dead timber in the Intermountain West has been estimated to exceed 6 billion cubic feet (Van Sickle and Benson 1978). Much of this volume is in lodgepole pine and has resulted from normal attrition in stagnated stands and more recently from the mountain pine beetle (Dendroctonous ponderosae (Hopk.)) epidemic. In 1981, an estimated 100 million cubic feet of lodgepole pine was killed by the mountain pine beetle in the western United States (USDA Forest Service 1982). I suspect that there are similar losses here in British Columbia.

BACKGROUND

LIFE CYCLE OF THE MOUNTAIN PINE BEETLE

The mountain pine beetle typically has a one-year life cycle (Furniss and Carolin, 1977). Mature insects fly from mid-July to August and during endemic infestations they tend to attack weaker, less vigorous trees that are normally eight inches and larger in diameter at breast height and over 100 years old. In epidemics the insects are less selective. Initial attack is by females; they mine galleries and lay eggs that hatch in about two weeks into larvae that overwinter in that stage. Pupation occurs in early July and with the emergence of adults the cycle begins again. In California two or three cycles may occur in one year; in colder climates and at high elevations one cycle may take two years.

Infested trees are recognized first by pitch tubes on their trunks and by red boring dust in bark crevices and on the ground at the roots. This is followed by discoloration of the foliage from normal green to light greenish yellow and then to reddish brown.

DETERIORATION

Deterioration occurs as a sequence of chronological events that overlap. First the tree stains, then it checks, and eventually it rots at the ground line and falls.

Lodgepole pine that has been attacked by the mountain pine beetle begins to deteriorate because of stain before it is dead. The blue stain fungus, mostly Ceratorystis sp. is introduced from pouchlike structures on the head of the beetle. Between 30 and 65 percent of the total main stem volume is stained within nine months (Harvey, 1979). By the time the needles have faded to the point that death is certain, the stain has generally infested the tree to the maximum extent possible (Figure 1).

EFFECT OF DETERIORATION ON PRODUCTS

The two primary factors affecting grade and volume losses from dead trees are stain and checks; the latter become splits in lumber or veneer. Heavy stain eliminates lumber from No. 2 Common and Better grades but has no effect on lower grades of Common lumber. It also has no effect on dimension and stud grades of lumber or core grades of veneer. Drying checks in trees are graded as splits in lumber and veneer. They generally limit the grade of boards to No. 3 or No. 4 Common; of dimension to Utility of No. 3; and of Studs to Economy Stud.

METHODS

The recovery information was taken from studies conducted in six mills at five locations in the Intermountain area (Figure 2); a board mill, a veneer mill, two dimension mills, and two stud mills. The same general techniques were used in all studies. Individual trees were selected, identified, and harvested. Logs were identified by tree and by position in the tree. At the mill, logs were scaled and during processing each piece of lumber or veneer was identified as to the log it came from. Product and log values were based on prices for surfaced dry lumber or dry trimmed veneer.

Tree diameters in our six samples ranged from seven inches to 22 inches with an overall average of about 12 inches. In any one study the diameter range may have been slightly different and the average may have been an inch more or less. The logs were scaled for both Scribner volume and cubic volume. As mentioned previously, the logs were converted into the mill's normal products, the lumber or veneer was identified back to the log, and products were graded and tallied in the dry condition. Sample measurements were taken to determine the actual green thickness and width of all products; product volumes are in cubic feet and are based on actual rough-green sizes.

PRODUCT PRICES

The values for lumber were developed by indexing prices taken from the Western Wood Products Association annual summary for 1978. Studs were set to $100 per thousand board feet and other items were set relative to studs. Veneer was priced at $49 per thousand square feet and chips at $48 per cunit. By indexing

the lumber prices it is easy to update to current prices. A method for doing this is shown in the compendium (Fahey and others in press).

ANALYSIS

In the analysis four dependent variables were evaluated as a function of gross cubic volume of the log:

1. Volume of lumber or veneer (cubic feet)
2. Volume of chips (cubic feet)
3. Value of primary product (dollars)
4. Value of primary product and chips (dollars)

RESULTS

Only the relationships developed for the four independent variables based on the board mill data are shown (Figure 3). The dimension mill, stud mill and veneer mill relationships are similar to the board mill and so won't be repeated here. All of these relationships are presented in much more detail in the compendium (Fahey and others in press).

In the board mill there was a sample of recent dead material. For the average log (12 cubic feet), 31 percent less volume was recovered from older dead trees than from live trees, but chip volume increased by 39 percent. Product value was 39 percent less for the older dead logs, but when the value of chips was included, the loss was reduced to 26 percent less than the value of live trees.

For the dimension mills, results are based on recovery from a sawmill in Wyoming with a circular headsaw and from a mill in Montana with a chipping headrig. Both studies were conducted in areas where no recent dead trees were available, so only live and older dead trees were sampled. The Wyoming mill recovered the same amount of lumber from the older dead trees as from the live trees. This was because although they did not have a good outlet for chips, they did save low grade lumber for a pallet plant that was adjacent to the sawmill. This mill experienced a 14 percent reduction in value for the older dead trees compared to live trees. The Montana mill had only a four percent loss in lumber volume for the older dead trees but a 21 percent loss in value of lumber and chips. Again, these comparisons are based on a log containing 12 cubic feet.

At the two studmills, one in Oregon and one in Wyoming, we were able to sample recent dead trees as well as older dead trees and live trees. At the Oregon mill there was no difference in either volume or total value in the recently killed trees versus the live trees. The older dead trees showed a lumber volume loss of five percent but a loss of only two percent in total value, as compared to the live trees. At the Wyoming mill there was a loss of seven percent in volume and nine percent in total value for both the recent dead and older dead trees. The Oregon mill made no attempt to increase recovery by salvaging small or poor quality lumber from the dead logs because they had a good outlet for chips. Conversely, the Wyoming mill obtained higher volume recovery from the dead sample but lower grade recovery and a corresponding lower value. By salvaging one-inch boards and 2 x 2's, the Wyoming mill, when compared to the Oregon mill, achieved the following: (1) Recovered more lumber for a given log volume, (2) obtained a higher average value for the lumber recovered from the live sample (No. 3 Common and Better boards are worth more than Studs), and (3) obtained lower average value of lumber from the dead sample because the small items saved from dead trees were of very low grade.

For the 12-cubic-foot log in the veneer study there was a 12 percent loss in both volume and value of veneer in the recent dead sample. These two items showed a 40 percent loss in the older dead sample. Loss in value of veneer plus chips was only five percent in the recent dead sample but 18 percent in the older dead sample.

SUMMARY AND CONCLUSIONS

Because staining occurs within a short time after trees die, harvesting trees before staining occurs will be extremely difficult. It may even be difficult to harvest them in time to prevent checking. During harvesting there may be higher losses due to breakage.

Stain and checks are the most important factors that reduce volume and value of lumber. Stain has the most effect on boards whereas checks will be more detrimental in structural lumber and core veneer. For the average-sized log (12 cubic feet), absolute values were highest for boards, followed by dimension, veneer and studs for both live and dead timber. The percentage of change in value from live to dead, however, showed the reverse order with studs losing the least value and boards the most. Please bear in mind that these values do not include costs of production.

Sawing dead logs will result in a higher proportion of low quality products and there may be difficulty in marketing some of them.

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Figure 1. Stain spores are carried by the mountain pine beetle. Fifty percent of the sapwood is stained within one month of beetle attack and the entire sapwood is stained within three months.

Figure 2. Approximate location of individual study areas and types of products at each location.

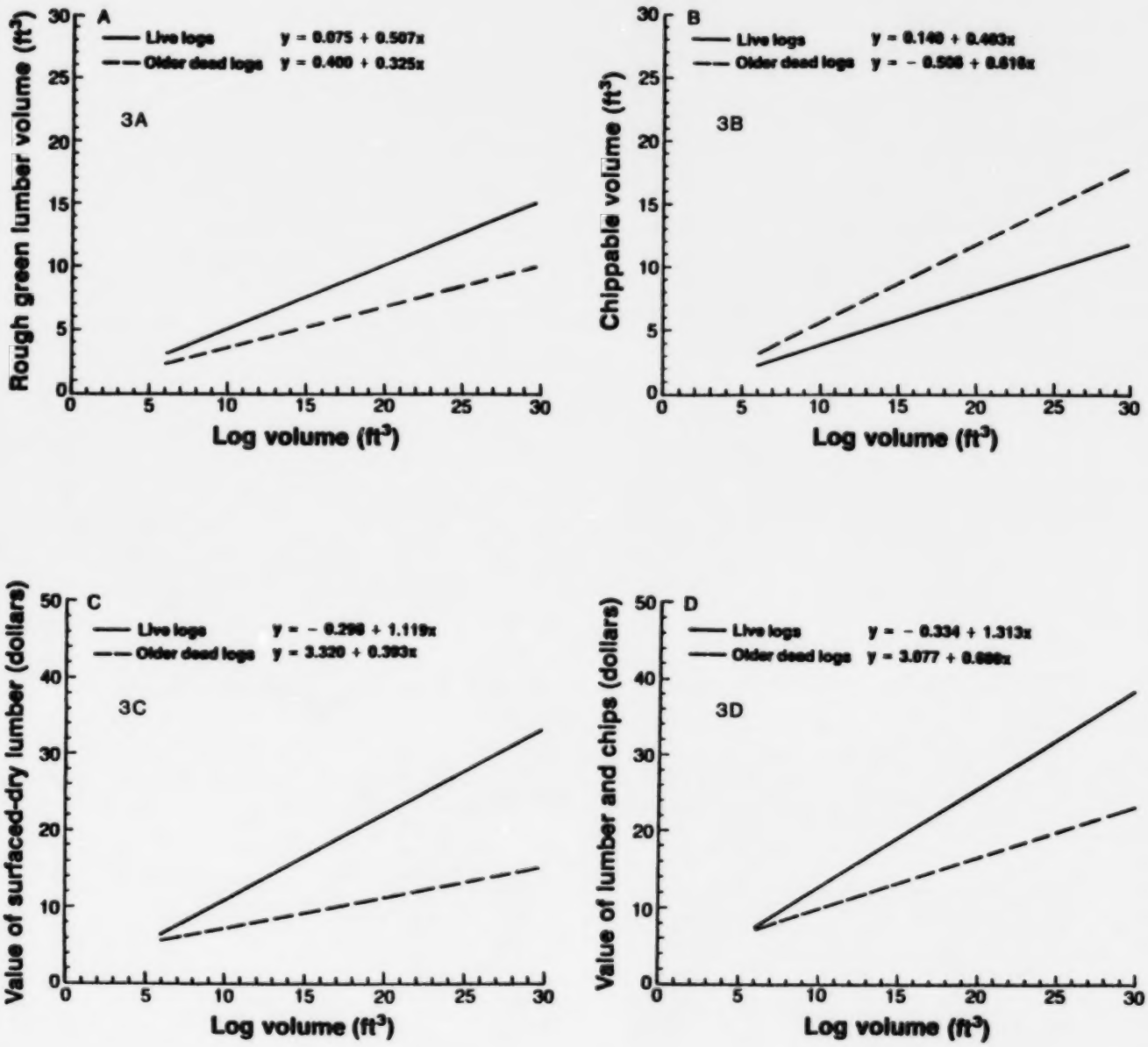
A
Live logs y = 0.075 + 0.507x
Older dead logs y = 0.400 + 0.325x
3A
Rough green lumber volume (ft³)
Log volume (ft³)
B
Live logs y = 0.140 + 0.483x
Older dead logs y = - 0.508 + 0.618x
3B
Chippable volume (ft³)
Log volume (ft³)
C
Live logs y = - 0.298 + 1.119x
Older dead logs y = 3.320 + 0.393x
3C
Value of surfaced-dry lumber (dollars)
Log volume (ft³)
D
Live logs y = - 0.334 + 1.313x
Older dead logs y = 3.077 + 0.888x
3D
Value of lumber and chips (dollars)
Log volume (ft³)

Figure 3. Volume and value estimates at a mill producing nominal one-inch boards from live and older dead lodgepole pine. (A) Cubic feet of rough-green lumber over cubic feet of gross log volume. (B) Cubic feet of chippable volume over cubic feet of gross log volume. (C) Value of finished lumber over cubic feet of gross log volume. (D) Value of lumber and chips over cubic feet of gross log volume.

SORTING OF DRY AND GREEN LODGEPOLE PINE BEFORE KILN DRYING

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One of the most frequently mentioned problems in relation to processing beetle-killed wood in the British Columbia Interior is that of kiln drying charges consisting of both green and partly dried stock. This results from the fact that dead beetle-killed stems are currently harvested and processed along with green stems from the same stands.

The losses, or additional costs, associated with the current procedures include the following:

1. extra cost to kiln dry already dry wood,
2. excessive degrade in the already dry stock, and
3. increased planer breakage due to overdry wood, and related planer production delays.

The purpose of this paper is to examine some possible alternatives available for dealing with this problem, the equipment changes required, the advantages and disadvantages of the alternatives and some related considerations. This is done within the framework of a series of studies designed to evaluate the economic merits of the alternatives.

PROPOSAL

In order to reduce the losses referred to above, it is proposed that the dry beetle-killed wood and green normal wood be segregated and the lumber dried separately.

MILL TYPE

The type of operation examined in the following alternatives is a typical British Columbian Interior spruce-pine-fir (S-P-F) dimension mill producing 2 x 4 to 2 x 10 in lengths from 8 to 20 feet, requiring 28 basic length and width sorts.

SORTING ALTERNATIVES

Four basic alternatives for sorting have been identified:

1. No change:
   - continue to run mixed dry and green stock (control) throughout the operation;

2. Sort in woods:
   - segregate dead (red top or older) from live stems as early as possible during harvesting. Haul them separately to the mill and store them separately in the yard;

3. Double the sorts:
   - this alternative requires doubling the number of sorts in a typical bin sorter, and adding an in-line moisture meter to identify and separate the dry from the green pieces;

4. Secondary sorting:
   - this is a compromise of the previous method in order to reduce the capital costs. It involves adding the same moisture detector, adding only a few bins for the entire dry sort, removing the dry sort of mixed lengths and widths, and feeding it back through the sorter using a re-entry system, either on a third or partial shift, or Saturday.

There are existing precedents for these last two alternatives, and all of the equipment required is available.

MOISTURE DETECTORS

Continuous moisture detectors, also known as in-line moisture meters and unstacker moisture meters have been available for several years. They are normally located on the dry chain between unstacker and planer. The meters are used to detect and to mark or reject lumber that fails to meet a preselected moisture content (MC) limit. Lumber that is rejected as being too wet can then be returned for further kiln drying, or treated as wet lumber.

It is proposed that a meter of this type be located on the green chain and used to segregate lumber into two sorts:

1. A 'dry sort', i.e., lumber that is at or below 25 to 30 percent MC, depending on the upper measuring limit of the meter; this sort would be either air-dried or kiln-dried using a shorter schedule.

2. The other sort would be the 'wets' which would proceed in the normal manner to the dry kilns.

Most electronic in-line meters presently available are claimed to be able to identify wood MCs over the range of six to eight percent up to around 27 percent. One supplier provides an optional sensor head with a claimed range of 10 to 150 percent MC.

Another system that could be used to make a segregation is based on the weight of individual boards, measured as they pass over a displacement transducer. This system, which is said to be in use in one or more Scandinavian mills, uses measurements of board length, width and thickness taken by the sorting system to calculate board volume. Using this board volume and average species density values, close estimates of MC can be made.

While it is doubtful whether a weight-based system would be as accurate as an electronic method using capacitance or dielectric loss, there is little doubt that it could be used to separate two groups, e.g., $\leq$ 25 percent MC and $\geq$35 percent MC.

ALTERNATIVES FOR DRYING THE DRY SORT

Once the lumber has been segregated into dry and green sorts, there are three options available for drying the dry wood:

1. Don't dry it - for wood at approximately 19 percent MC,

2. Air dry it - under appropriate climatic conditions,

3. Kiln dry it - for a shorter period, possibly at higher temperatures than normally used since the danger period for degrade is already past.

Obviously the moisture content of the dry sort will have a direct bearing on the option chosen. The moisture content distribution

will be largely determined by the length of time since the trees were killed. Since any given stand that is salvaged could contain trees killed over a period of several years, there could be a significant variation in MC among pieces in the dry sort.

Very little data exist on the MC distribution in the dead trees in B.C. However, it will obviously depend on whether the trees salvaged are from green attack, red attack, or grey attack areas. Data from Reid (1961), shown in Figure 1, do indicate that the outer sapwood reaches fibre saturation point (FSP) about one year after attack, based on a study carried out near Invermere, B.C. and Banff, Alberta.

Table 1 contains data from Idaho (Tegethoff, et al., 1977) which indicate that the wood of trees in the range of one to three years since death will largely be below FSP, although some heartwood pieces would likely remain above FSP.

Another factor which will determine whether the lumber is kiln dried or not is the intended market. If the lumber is to be exported offshore, kiln drying may be required to sterilize the lumber, and the minimum drying conditions may be specified by authorities in importing countries. The following are examples of sterilization schedules:

U.K. a) 5 hr. @ 140°F @ 100 percent relative humidity

b) 6 hr. @ 135°F @ 100 percent relative humidity

Australia 6 hr. @ 165°F

EVALUATION OF ALTERNATIVES

To properly evaluate the three sorting alternatives relative to the current situation, several estimates must be made:

- the savings in costs which would result from sorting,
- the additional capital and operating costs involved in sorting,
- the resulting net dollar benefit.

Savings Due to Sorting

The savings anticipated from reduced drying costs will be much the same regardless of how the sort is made. The savings include:

a) reduced cost to dry the dry sort,

b) reduced degrade in the dry sort,

c) reduced breakage at the planer, and reduced downtime resulting in higher throughput and lower unit costs.

To precisely quantify these savings is a large task involving studies of each category of savings using dry sort samples and control samples. Although these studies have not been done, it is possible to examine some aspects of the potential savings on a theoretical basis.

Reduced drying cost. The savings in drying cost will depend on several factors:

- the proportion of the total production in the dry sort,
- the moisture content of the dry sort, and
- whether the dry sort needs further drying in the kilns or is acceptable as is.

If the wood is sufficiently dry, and no further kiln drying is required, a significant reduction in drying cost is possible. Costs fully or partly eliminated would include:

- kiln heating costs,
- electrical costs,
- labor for loading and unloading the kilns,
- sticker costs,
- kiln maintenance costs.

While the absolute amount saved is a site-specific question, savings in the order of $3 to $6/Mfbm or perhaps higher for the dry sort lumber would be possible.

The savings would drop significantly if drying must be completed in the kilns. This would eliminate the savings in sticker and handling costs, and reduce the savings in energy and electrical costs.

Table 2 indicates drying times for lodgepole pine using two typical schedules, and based on four levels of initial MC. These are mathematically derived data based on a Western Laboratory report "Calculating Kiln Schedule Changes" by G. Bramhall (1975). It can be seen that regardless of kiln schedule, if the initial MC of the dry sort lumber is 30 or 25 percent, drying time can be reduced by approximately one-fifth or one-third respectively.

Reduced degrade cost. The second source of saving would be a reduction in degrade, accomplished by not overdrying the dry stock. This could be a significant saving, but a degrade study would be needed to quantify it. This would involve making degrade estimates for both a sample containing mixed green and dry lumber, and a sample of dry sort lumber.

The study requires establishing a grade and trim length for each sample piece before drying and after drying. These would be combined with price data to estimate the amount of degrade for the mixed and dry sort alternatives, and the potential savings in degrade.

This degrade study would be very difficult and expensive to execute at a mill due to the need to accumulate and sticker sufficient 'dry' sort lumber for an entire kiln charge. An alternative procedure would be to select smaller samples of control and dry sort lumber at the mill for drying in a smaller research kiln.

Reduce Planer Breakage. To determine how much planer breakage and associated delays could be avoided by not overdrying beetle-killed wood in mixed green and dry charges, a planer study would be required. Data collected over several shifts would include:

- duration of each delay,
- reason for delay,
- moisture content of pieces broken and removed from the planer.

From these data, an estimate of the potential reductions in planer breakage and planing costs can be obtained.

Other Benefits of Sorting by MC. In the case of both sorting methods performed at the sawmill (Double the Sorts and Secondary Sorting), the savings are limited to those outlined above.

If, however, dead stems are sorted from live stems in the woods, there exists the potential to make further savings, particularly through reduced breakage. This opportunity arises because barker tools or pressure may be altered to suit the log conditions if either all dry or all green wood is being processed at any one time.

Another opportunity arising if dry stems are sorted in the woods is to better control the storage time and storage conditions for these stems. The dead stems can then be processed sooner, minimizing further deterioration in storage, or water sprays can be applied without affecting green stems at the same time.

A further benefit may be obtained if the dry stems are separated and stored in water or under water sprays. The resulting increase in MC should serve to reduce the proportion of chip fines which is higher in dry than in green wood.

Cost of Sorting

The other side of the economic evaluation is to estimate the costs of implementing each of the three sorting alternatives.

Sort in the woods. This alternative should not require any new capital expenditures, assuming that existing equipment can handle the sorting.

Since some species and size sorts are already being made at woods' landings using delimbing and front-end loading equipment, applying the same techniques to sort green and dry stems should not present any new problems, providing the number of sorts is within reason.

The cost to implement this alternative is strictly in the form of increased operating costs. No capital investment is required.

Double the sorts. This alternative is the one requiring the largest capital investment, involving outlays for:

- double the number of bins,
- extension of the building and transfer chains to the stacker,
- an in-line moisture detection system.

A small increase in operating and maintenance costs can also be expected.

Secondary sorting. The idea behind a secondary sorting system is to reduce the number of additional bins required to make the dry sort. This saves some of the capital cost of extra bins, building and transfer chain extension. However, a re-entry system is now required to feed the dry sort back to the sorter on a third shift or on Saturdays to complete the sort and run it through the stacker. The in-line moisture meter is required as before.

While some capital is saved with this option, operating expenses are higher for sorting and stacking; these costs will double for the dry sort if run on a third shift, and more than double if the re-sort is done on a Saturday, involving overtime rates.

This option also has a severe logistical disadvantage in that partially loaded bins of green wood should be emptied before commencing the final sort of the dry material.

A further observaton on the nature of the overall problem and the level of risk is in order. If there is very limited knowledge of the number of years that dead timber will be processed at a specific mill, the risk involved in the capital investment is large. It is questionable whether a large investment should be made if there is no assurance that the equipment will be used over its useful life, or perhaps even long enough to pay off the investment.

Net Benefits Due to Sorting

Once the costs and savings for each alternative have been established, the net benefits of sorting can be estimated and a choice made between alternatives.

For this particular problem, the net present value of each alternative can be calculated and the one with the highest positive value selected as the best.

Alternatively, if the savings obtainable from sorting are assumed to be identical, regardless of how the sort is achieved, the selection could be based on the least cost alternative, with the costs expressed on an equivalent uniform annual cost basis.

CONCLUSIONS

While a detailed analysis of the above type has not been completed, a few relevant points are in order to sum up this discussion.

First, by its very nature, the problem is a highly variable one in the degree to which it will affect any given mill over a period of years. It therefore becomes very difficult to quantify the savings obtainable from sorting and drying the dry wood separately.

Second, only sorting in the woods provides an opportunity to obtain benefits from sorting in addition to reduced drying costs.

Third, only sorting in the woods eliminates the need for questionable capital expenditures.

Fourth, only sorting in the woods provides the opportunity to adjust the total sorting cost in direct proportion to the amount of beetle-killed wood handled from one operating period to another.

While these points certainly favor sorting in the woods and running beetle-killed wood separately through the entire milling process, this alternative is not without its problems. The major one, which is common to all three sorting methods, is in marketing packages in which virtually all the pieces are blue-stained. Perhaps continuing the work of the blue-stain fungi and staining the entire piece could provide a solution.

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Table 1.

Average MC (% and Standard Error) of Wood from Beetle-Killed Lodgepole Pine in Relation to Time Since Death

Height in Tree	Years Since Trees Died			
	1 - 3		3 - 5	
(ft.)	Sapwood	Heartwood	Sapwood	Heartwood
1	47 ± 15	20 ± 3	31 ± 11	29 ± 5
16 - 19	20 ± 3	26 ± 8	15 ± 5	16 ± 4
35 - 40	25 ± (1)	27 ± (1)	12 ± 2	14 ± 2

(1) one measurement only.
Source: Tegethoff et al., 1977.

Table 2

Estimated Drying Time from Initial MC to Average 15% MC for Lodgepole Pine Dimension Lumber

Initial MC	Drying Time (hr.)	
(%)	Schedule 1	Schedule 2
50	56	37
40	52	34.5
30	44	30
25	37	26

Schedule 1: 180°F-160°F for 10 hours, 190°F-160°F for balance to 15% MC
Schedule 2: 180°F-160°F for 10 hours, 200°F-150°F for balance to 15% MC

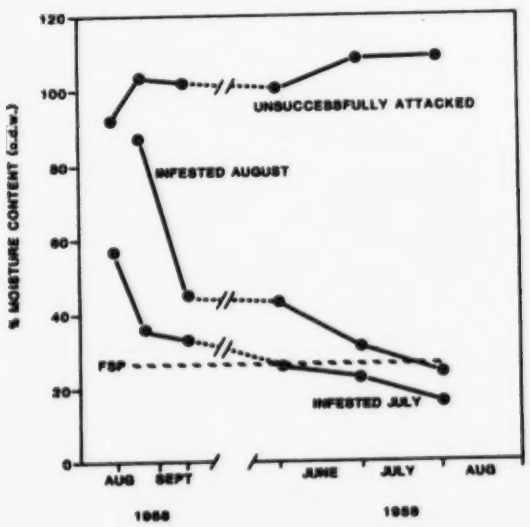

Figure 1. Outer sapwood moisture content of successfully and unsuccessfully infested lodgepole pine at 3 1/2 feet above ground.

Source: Reid, 1961.

INFESTATION BY PINE AND SPRUCE BARK BEETLES IN BRITISH COLUMBIA AND ITS EFFECT ON KRAFT AND MECHANICAL PULPING

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ABSTRACT

Samples of pine and spruce beetle-killed wood were collected at various stages of time since attack. Wood characteristics, debarking wood losses and chip quality were measured. The furnishes were kraft cooked and pulping characteristics determined. Kraft pulp quality, drainage, drying and bleaching characteristics were assessed. Blue stain, which occurs in beetle-attacked wood, was evaluated for its effect on kraft and mechanical pulp quality and bleachability. Chemithermomechanical pulping and bleaching were carried out on both the spruce and pine. The effect of including beetle-killed wood chips with unattacked wood on chip pile deterioration has been assessed. This report presents the general findings of this study. For further detail, see P.R. Thomas' Econotech Report to BCSC, April, 1985.

CONCLUSIONS

1. Beetles attack the top quality trees.
2. Wood substance losses increase in the forest due to loss with ageing of dead wood and increased fragility during logging and transportation.
3. Blue staining occurs very rapidly after attack for both pine and spruce.
4. Loss of pine good wood during debarking increases slowly with time since attack until the later grey stages, where it increases. Losses with spruce are more severe.
5. Chip fines increased with increased time after infestation.
6. Wood moisture decreased with time after attack.
7. Wood density decreased with time after attack.
8. One percent caustic solubility increased slightly with time after attack.
9. Kraft pulping alkali requirement was almost constant with the different categories of pine and increased slightly with the spruce.
10. Pulp viscosity was reduced for the oldest categories of spruce and for the oldest whole log pine pulp.
11. The whole log and slab pine and spruce samples showed an increasing loss in kraft pulp yield with time after attack.
12. Black liquor tall oil content increased significantly with beetle attack and then decreased as time after attack increased.
13. Black liquor solids content increased with time after attack.
14. Beetle attack caused no significant differences in the bleachability of kraft pulp.
15. The pine kraft pulps show maximum strength at the green to red top stage and reduced strength in the older grey stages. The spruce pulps show de- creased strength at the red top and grey stages.
16. Beetle-attacked wood pulp is likely to show poor pressing/drainage characteristics.
17. Old beetle-attacked wood is susceptible to damage from mechanical action in pulping.
18. Incorporation of beetle-killed wood chips in chip piles is not likely to increase deterioration and wood loss.
19. CTMP tear usually decreases with increased time after attack.
20. CTMP shows poorer bleaching response with increased time after attack.
21. Effluent toxicity and pitch problems could increase for chemical and mechanical pulp mills.

RECOMMENDATIONS

1. Mills using beetle-killed wood should use the data in this report and that by Thomas (1985) to assess the total impact on their operations and to negotiate an appropriate price for this raw material.
2. Pine or spruce beetle-attacked wood should be harvested as soon after attack as is economically feasible.

INTRODUCTION

A. Mountain Pine Beetle

The mountain pine beetle (Dendroctonus Ponderosae Hopk.) is the greatest insect enemy of mature lodgepole pine in Canada. It is also very active in other Western North American areas such as Alberta, Washington, Idaho and Montana. Affected to a lesser extent are western white pine, ponderosa pine, other pines and, infrequently, other species. An excellent coloured publication on the mountain pine beetle, describing life history, tree symptoms, management guidelines and literature to 1973, was published by Environment Canada in 1974 (Safranyik, Shrimpton and Whitney, 1974).

The extent of infestation and damage is massive. The history and degree of infestation in Western North America has been well documented by Van Sickle (1982). The joint Canada/USA workshop on Mountain Pine Beetle Related Problems in Western North America (Shrimpton (Ed.), 1982), covered a wide range of topics from biology through case studies to current and required actions and research needs. The impact on the economy of British Columbia was also addressed at this workshop by G.H. Manning of Environment Canada. Suggested losses to British Columbia are several hundred million dollars per year.

The impact of this beetle has been assessed yearly by Environment Canada. Wood and Van Sickle (1982) determined that the beetle attack in 1981 killed more than 55 million trees (15.7 million cubic meters) and probably slightly fewer in 1982 and 1983. The extent of pine beetle activity in 1982 is illustrated in Figure 1 (Wood and Van Sickle, 1982). Other types of pine beetles are active in different areas of North America, e.g. the southern pine bark beetle (Dendroctonus Frontalis Zimm.) and are responsible for widespread tree mortal- ities (Ifju, et al., 1979; Hitchings and Levi, 1981).

A list of the whole range of insects associated with native pines in British Columbia has been compiled by Environment Canada (Evans, 1983).

The evaluation of damage from mountain pine beetle has been aided by advances in aerial photography by Environment Canada (Harris, Dawson, and Brown, 1982 and 1983). Control methods for the pine beetle are discussed by Safranyik, Shrimpton and Whitney (1974) and Shrimpton (Ed.) (1982). More recent methods have included experiments with semiochemicals (Cerezke, Borden, and Trott, 1984). The effectiveness of these chemicals is still uncertain.

The impact of insect-attacked trees on the solid wood products industry has been extensively studied and pine beetle-killed wood is no exception (see Other Relevant Literature section).

B. Spruce Bark Beetle

Although not as serious a pest as the mountain pine beetle, the spruce beetle (Dendroctonus Rufipennis) does cause major damage in British Columbia. The extent of the attacks has been documented by Wood and Van Sickle (1982) and is serious in Southeastern B.C. and in the Cariboo, Prince George and Prince Rupert forest regions (see Figure 2). Compared with studies of the mountain pine beetle, very little work has been carried out on the spruce bark beetle.

SPECIFIC BACKGROUND FOR THIS STUDY

The pulp and paper research centre of Econotech carries out, on a world-wide basis, projects relative to the impact of wood and chip quality on the pulp and paper industry. This background in resource quality and utilization lead the pulp and paper industry of British Columbia to approach Econotech concerning the impact of pine and spruce beetle-killed wood on their operations. The degree of infestation and the general wood supply situation was leading to increased potential and actual usage of beetle-killed wood (Westergaard, 1983; Montgomery, 1983; Wolfe, 1983). In recent years, the proportion of pine in the wood furnish to some interior mills has increased due to the necessity of cleaning out stands of beetle-killed pine. This can lead to a significant proportion of the mill furnish consisting of beetle-killed pine. In addition, some of the interior mills have started to receive considerable quantities of beetle-killed spruce, and Econotech was specifically requested to include spruce in the study. Other key areas noted by the pulp companies were wood handling losses, chipping effects, effects on digester operation, yield, quality, pulp machine capacity and pulp drying rates. Mechanical pulp producers were interested in the effects on quality and brightness. The industry was also concerned about accelerated aging effects in chip piles and effects related to pitch and resin content. The effects of blue stain, which is increased by beetle attack, were of major concern to some of our customers.

PREVIOUS KNOWLEDGE

In dealing with insect-attacked trees or any dead, dying or diseased wood, we are looking at a very wide range in material characteristics. This range can cover wood which is barely distinguishable from normal healthy green wood, all the way through to timber with advanced decay. Any competent woods operator or chip supply supervisor at a pulp mill can confirm that the effects of such material can be undetectable or can be very severe. The most obvious and well-known effects are extremely variable wood losses in wood handling, debarking and chipping operations. If the situation extends into rot, then the effects of this in both wood handling and pulping operations are also well known and very variable. In its routine resource evaluations for companies across Canada, the United States and abroad, Econotech has confirmed the variable nature of the effects of death and disease on the wood handling and pulping operations. A large quantity of work has also been carried out in the United States on dead softwood timber. Much work has also been carried out by private companies. These efforts go back over many decades and the results show that each situation can be very different depending upon climatic conditions, many forest factors, methods of wood handling and the specific processes used in the pulp mills. Specific data on factors such as wood density, pulp yield and quality are also included in these descriptions of variability, with some investigators finding little or no change and some finding major changes.

Specific work on pine beetle-killed wood has been considerable with respect to solid wood products (see Introduction). Work relative to pulping is limited. Some work has been carried out on southern pine beetle-killed trees (Ifju, et al., 1979; Hitchings and Levi, 1981) where results showed no effect on pulp yield up to two years after death and some loss in specific gravity and pulp strength. Thermomechanical pulping of dead softwood trees was carried out by Troxell, et al. (31) with promising results. A very small amount of work on pulping a single sample of dead lodgepole pine was carried out by Lowery, et al. (1977). The kraft pulping showed good yield seven years after death, but there was no control. This particular sample had virtually no decay. They also confirmed the well-known increase in horsepower required for chipping the relatively dry wood and the increase in chip fines content. Pulping of green and insect-killed lodgepole pine was carried out in 1951 by the USDA and they also referred to commercial pulping tests of green versus dead lodgepole pine (McGovern, 1951; Report No. 287, Thilmany Pulp and Paper Co.). The USDA work showed increased wood densities for the insect-killed trees. Kraft pulping showed very little effect on yield and only a slight effect on strength. Onset of rot reduced yield and strength. With sulphite pulps, slightly reduced yield and increased burst and tensile, but reduced tear were shown.

None of the work described in the above investigations answered the key questions posed by the British Columbia pulp and paper industry for the utilization of insect-killed pine and spruce in this province. In addition, all the work was carried out on whole tree chips. The change in wood utilization patterns has made

it a requirement that meaningful resource evaluations be carried out either on slab or whole stem wood, depending on a company's utilization of residual or whole stem chips. Consequently, modern studies may look at the characteristics of both slab wood and whole stem wood.

OBJECTIVES

The objectives of this study were to assess the effects of pine and spruce beetle attack on:

1. wood characteristics,
2. debarking wood losses,
3. chip quality,
4. kraft pulping, yield and quality,
5. kraft pulp drainage and drying characteristics,
6. kraft pulp bleaching,
7. blue stain development and its effects on kraft and mechanical pulp,
8. chemithermomechanical pulping quality and bleachability, and
9. effect of beetle-killed wood on chip pile deterioration.

WOOD COLLECTION

A. Lodgepole Pine

The pine samples for this study were collected from the Midway area of Southeastern B.C. Major assistance in the form of manpower, road and logging equipment was provided by Pope and Talbot. Very valuable assistance was also provided by one of Environment Canada's experts in this field, Colin Wood, of the Pacific Forest Research Centre near Duncan on Vancouver Island. The collection was carried out during the second week of June 1983 and at that time the pine bark beetles were already in flight.

In order to obtain an easy, practical application to the forest scene, it was decided to categorize the pine in five stages which were easily visible to the eye. These were:

1. Unattacked green trees to act as control.
2. Green trees, but beetle-attacked.
3. Red top trees. This stage is usually developed two years after attack.
4. Grey bark attached. At this stage, the tree has reached a point where there is little or no foliage, but the bark still remains attached to the tree.
5. Grey with loose or no bark. The tree at this stage has no foliage and either no bark or very loosely attached bark.

For each of the above categories, six trees were selected with a minimum of other abnormalities. The trees were of average size for the stand. After felling, a 1.2 meter bolt was cut from the merchantable top of the tree (typical average diameter 10-15 cm) and another 120 cm long bolt was cut at breast height. The logs were immediately transported by truck to Econotech where they were weighed and debarked, weighed again and measured. The extent of blue stain and the age of the trees were also measured. The trees were typically 70 to 120 years old with breast height diameters in the range of 18 to 30 cm. As described by Safranyik, et al. (1974) and by Colin Wood on site, the following is the usual sequence of crown symptoms resultant from mountain pine beetle attack.

The green trees are usually attacked in the summer starting in May or June but the first noticeable foliage colour change does not normally occur until spring of the following year. Some fading will occur in the first fall if there has been an early attack and a hot, dry summer. The foliage changes from green to yellow, to yellow-brown and to red-brown and then finally drops off the tree. In June and July of the year after attack, the trees are usually yellow-green or yellow-brown and one year later the trees have definite red tops. The red-brown colour may appear to some extent one year earlier than this. Three years after the attack there is usually very little foliage left, although a few red-brown needles may be retained up to three years. It was also noticed that the beetles preferred to attack the larger trees.

Occasionally the trees were able to successfully defend themselves by massive pitch production which pushed the beetles back out of the trees. These were locally referred to as "right pitched out".

Most of the green attacked trees had been infested in 1982, the red tops in 1981, and the grey with tight bark somewhere in the years 1977-80, but more commonly 1980. It was also noted that some of the green attacked trees had been subjected to "strip attack". In these cases, the beetle attacks a preferred side of the tree only. This sort of attack and modifications of it result in variable attack by associated fungi, e.g. blue stain. Since the bark beetles like fairly thick bark in which to construct their galleries and also bark with nice niches to get started in, the degree of attack decreases up the tree. This results in less blue stain in the upper portions (see below).

Another important aspect of the mountain pine beetle is that it is associated and lives beneficially with two blue stain fungi. Consequently, as soon as the tree is attacked by beetles, it is also innoculated by blue stain fungi. The fungi spread both vertically and radially and, with time, the whole tree is affected by blue stain. As expected, the trees showed significant blue stain in the sapwood of the breast high bolts. There was no blue stain in the top bolts of these trees or in the trees which had been "right pitched out". The percent of circumference affected by the blue stain was very variable, partly due to modifications of the "strip attack" noted earlier. In general, the degree of blue stain increased with time after attack.

B. Englemann Spruce

Samples of Englemann spruce were collected in mid-September from the Nakusp area of southeastern British Columbia. As with the pine beetle, the spruce beetles seemed to prefer the biggest and the best trees and consequently a major logging effort was required to extract timber for this study. This was very generously carried out by Westar Timber Ltd. Timber diameter was up to 84 cm at breast height. Three cataegories of wood were collected:

1. Green-topped (unattacked by beetle) to act as control.
2. Red-topped, normally two years after attack by the beetle.
3. Grey, no foliage and variable bark adhesion.

There was some blue staining of the red top and grey categories.

ESTIMATES OF POTENTIAL DEBARKING LOSSES

It is very well known by those familiar with debarking that major wood losses can occur with the debarking of dried checked wood or wood deteriorating from rot or other causes. This can occur in both mechanical and hydraulic debarking systems. The extent to which this occurs will depend upon the type of debarking equipment, how it is operated, the dryness and density of wood and the degree of checking.

Each situation will be site specific. Many previous Econotech projects on the effects of wood deterioration have shown the expected very wide variation in potential wood loss. However, it was still considered useful with the wood on hand to carry out two simple tests to look at differences between the different grades of wood. The absolute figures generated, although useful as a possible potential wood loss, must be considered with the above in mind.

A. Lodgepole Pine

The top bolts of the lodgepole pine trees which had previously been hand debarked (inner and outer bark) were reweighed immediately prior to passing through a small cambio ring debarker at the British Columbia Institute of Technology in Burnaby, B.C. The breast height bolts were too thick to pass through this equipment. The bolts were reweighed after passing through the debarker and the wood loss calculated. Owing to the relatively short bolts (1.2 meters), wood loss could be slightly exaggereted in this system due to the short bolts and extra tendency for wood to split, particularly in the drier, checked specimens. The good wood loss characteristics are summarized in Figures 3 and 4. The results show a slight increase in the potential for good wood loss during debarking up to and including the grey with tight bark stage. Even a small good wood loss of approximately 0.4 percent as shown here could be very significant to a large operation. In the category of grey with loose or no bark, a major increase in the amount of good wood loss was shown. As expected, there was a wide spread in the data shown by this category.

A further experiment was carried out on the base bolts by removing a six-inch section of the bolt, weighing it, mounting it in a lathe and applying a four point tool with a pressure of 45 kg. Results (see Figures 3 and 4) confirm the easier loss of material via a scraping tool as time since beetle attack increases. These effects would be the result of increased checking, decreased wood moisture, increased deterioration and decreased wood density.

B. Spruce

Trials similar to those carried out on the lodgepole pine were also carried out with spruce. However, due to the very large size of the breast height bolts from this species, all work was carried out on top bolts. Results are given in Figures 3 and 4. Some trouble was experienced with the cambio debarker, in that the tool pressure was too high and could not be reduced at that time. This gave unrealistically high wood losses for this equipment. The bolt diameter problems lead to a relatively small number of samples being tested and, consequently, the significance of the data is not as good as that with the pine results. However, the data do indicate that good wood losses did increase with length of time since attack. With allowance for the above, the losses up to the red top stage are likely to be small, compared with those experienced at the grey stage. The effects of the cambio debarking were exaggerated not only due to the tool pressure, but also due to the effect of the shorter bolts as noted above for lodgepole pine.

CHIPPING AND CHIP CHARACTERISTICS

All the bolts were adjusted so that their lengths were approximately 105 cm. One half of each bolt was slabbed to yield a cant of square cross section with the points reaching close to the surface of the log. In each tree category, slabs were taken from the butt end of the bolt for half of the bolts and from the top end of the bolt for the other half, unless an even number prevented exact divisions of this type. The cants produced were not used. Chipping was carried out in the Econotech 40-inch, six-knife CAE chipper which has gravity feed and a V anvil. The order of chipping was carried out so as to randomize any effects of change in the chipper with time. Chips were combined to give composite samples for slabs and whole stem chips for each tree category.

Chip quality was determined using a Stalsvetz classifier, equipped with 45 mm round hole, 10 mm slot, 7 mm round hole, and 3 mm round hole screens. In the case of both pine and spruce (but worse with the spruce) there was a major increase in the quantity of fines produced with increased time after infestation. This is shown in Figures 5 and 6. The increase in fines is the expected result of increasing dryness of the wood and increased checking. The increase in fines content can have very serious implications. If the increased fines are efficiently screened out, there will normally be a value loss due to decreased value as hog fuel. If the fines are not efficiently screened out and the fines content is increased in the mill digester feed, then there can be decreased uniformity of cooking in the digester (both continuous and batch), possible decreased productivity in the digester, poor drainage characteristics, possibly leading to reduced production and impairment of physical strength characteristics.

WOOD MOISTURE CONTENT

The chips were tested for moisture content and, as expected, there was a significant decrease in moisture content with time after attack. A major decrease in moisture content was observed for both species. This is partly a result of the climatic conditions typical for the species under consideration. The decrease in moisture results in severe checking already showing up at the red top stage. This significantly reduces lumber values and increases pressure for whole tree chipping for this type of material or for other uses, such as flakeboard or firewood. The increased dryness produces lower quality chips and also increases the power requirements in chipping. Typical industry figures for increase in power requirement with decrease in moisture content would be approximately a one percent increase in power per one percent decrease in moisture content.

There are other major implications for the reduced moisture content other than those noted above for the effects on chip physical quality. Dependent upon mill pulping equipment and pulping conditions, the effects of reduced moisture into the pulping process can

be severe. For short cycle systems with poor impregnation or presteaming, reduced moisture can impair impregnation, leading to high rejects and poor quality. A major problem is variable moisture content, and the presence of relatively dry chips in a mill furnish may occur as slugs. If this is the case, the plug movement of a continuous digester can be seriously impaired with consequent variation in K number and cooking uniformity. This situation can be made considerably better by improved presteaming and/or impregnation.

WOOD DENSITY

Wood density data are illustrated in Figure 7. There was a noticeable decrease in this parameter with time after attack. If wood purchases are being carried out on a volume basis, a decrease in wood density could mean a significant increase in basic wood costs. The lower density can also have other adverse effects. One of these is increase in chip transportation costs due to decreased loading of rail or road cars. Depending upon a mill's ability to determine oven dry wood feed to the digester on a continuous basis, changes in wood density can have the effect of causing swings in K number if the content of the drier material is variable. The lower wood density will also bring about reduced capacity of batch digester systems and will require feeder and cooking condition changes to maintain productivity in continous digester systems. The worst situations arise when the content of the different wood is a variable factor in the feed. As noted earlier, reduced wood density will increase susceptibility to mechanical damage and loss of wood in wood processing.

ONE PERCENT CAUSTIC SOLUBILITIES

Although there is some scatter in the one percent caustic solubility data, there is a clear-cut tendency for caustic solubility to increase with time after attack. Increased caustic solubility is sometimes related to an increased caustic requirement in kraft pulping. The pulping data indicated that this was true to a slight extent for the whole log pine chips but not the pine slab chips. A slight effect was also observed for the spruce whole log and slab chips.

KRAFT PULPING

Kraft pulping was carried out in a 60 litre digester equipped with indirect heating. The data show that for the lodgepole pine chips there was very little change in alkali requirement to achieve target K number. There was some slight variation between the different wood categories. Pulp viscosity was notably reduced for the oldest category of whole log pine. In the case of the slab pine chips, this was not the case. The whole log and slab pine samples showed a significant drop in yield with time after attack (see Figure 8). This was most marked in the later years and was most severe in the case of the whole log pine chips. The black liquor, tall oil content increased significantly over the control and then dropped with the older stages (see Figure 9). The increases are presumably due to the defense mechanism of the tree against beetle attack. Beetle-killed wood could increase toxicity of effluents due to increased extractives content.

In the case of the spruce pulping, there was a slight increase in alkali demand with time after attack. There was also a significant drop in viscosity noted for the grey stage wood. As with the pine, there was a significant loss in yield with time after attack and, also similarly to pine, the drop in yield was most significant at the grey stage with the whole log samples (see Figure 10). There was a corresponding increase in black liquor total solids content which could mean loss of production for recovery-limited mills. The spruce cooking also showed a slight increase in tall oil and then a dropoff as time after attack increased. These differences, however, were not as significant as with the pine, which is a high tall oil wood.

BLEACHING OF KRAFT PULPS

The pine and spruce kraft pulps were bleached using the CEDED sequence with variation of chlorine for variable starting K number and variation in the D1 stage according to CE K number. The results showed no major differences in the bleaching characteristics of these pulps except for an indication that the control spruce slab pulp was relatively easy bleaching. There were no significant differences in finished pulp viscosity for the pine pulps, whereas the spruce grey stage pulps did show significantly lower viscosities for pine pulps than spruce pulps.

KRAFT PULP STRENGTH CHARACTERISTICS

The bleached kraft pine and spruce pulps were subjected to PFI beating evaluations with results summarized in Figures 11 to 14.

In the case of the pine pulps, there is an interesting maximum in strength characteristics for the green top whole log pulps. After these stages, the strengths at constant freeness decline to the grey stages where the strengths, in terms of burst and tensile drop below that of the control pulp. In the case of tear, there is agreater loss. In the case of the slab pulps, the improved strength extends to the red top stage and loss of burst as well as tear strength is significant. The maxima could be due to increased fines or to the beetle selecting the best trees. If due to fines, it may not be observed in mill practice where fines are probably higher. In terms of fibre mat characteristics, the pine pulps show significant changes with time after attack. There is an initial increase in bulk figure and decrease in porosity figure, followed by steady decline and increase in these characteristics, respectively. This data, which is obtained on an air dry sheet, may have some relevance to sheet characteristics at higher moisture content which could affect drainage and drying characteristics (see next section). In general, it can be stated that in the case of pine pulps there should be no problem with strength characteristics up to the red top stage, although there could be an increase in refining power requirements. Wood used after the red top stage could give reduction in strength.

In the case of the spruce pulps, there was a significant drop in strength at constant freeness when comparing the red top pulps with those of the control. The tear continued to drop with increase in age to the grey stage but the burst and tensile tended to level off. There was a major increase in porosity figure even at the red top stage, with extremely high figures being reached at the lower freeness levels. As with the pine, these figures which relate to sheet charac-

teristics may be of significance relative to drainage and drying even though they are measured at very high consistency.

DRAINAGE AND DRYING CHARACTERISTICS

Work by Econotech on other projects has indicated that the productivity of the machine/dryer system can be severely impaired by the use of old, dry but not rotted wood. It is well known that wood containing rot can cause poor drainage characteristics and this will occur if the beetle-killed wood becomes rotten at some stage.

Although a controversial subject, unbeaten freeness frequently give an indication of drainage characteristics. In the case of the pine pulps, the unbeaten freeness increased at the green top stage and then declined. This was true for both whole logs and slabs, although the changes with the slabs were very small. The freeness therefore gives some suggestion that there may be drainage problems with older beetle-attacked pine. In the case of the spruce, the effects on freeness were more pronounced and some impairment of drainage would be expected.

A good indication of the changing characteristics of the pulp mat with change in time since beetle attack is shown by the air dry porosity figures. The differences are most marked at lower freeness but are very apparent even at high freenesses. The air dry porosities at 600 Canadian Standard Freeness show an initial drop in figures with the green top stage for pine, followed by a steady rise. Higher figures mean lower sheet porosity. The increase was more marked for the spruce pulps, particularly at the grey stage. Although this measurement is made for the passage of air at air dry consistency, it does indicate a significant difference in the nature of the fibres, which could relate to drainage and drying characteristics.

TAPPI drainage rates were measured on the pulps (simple drainage in a British Sheet Machine). No significant trends were noted with this test.

Econotech has developed some special tests to evaluate pressing and drying characteristics. One of these tests is the pressing time of a previously formed pad of pulp in order to achieve a consistency in the low 30's. This would typically be 32 or 34 percent consistency. This test showed up significant increases in time required to achieve the target consistency (see Figures 15 and 16). This was true for all the classes of pulp measured as time from beetle attack increased. This would indicate a decrease in the efficiency of wet pressing as time from insect attack increased. It was also noted that the spruce, per se, was much more difficult to press than the pine. The pulp produced in the above test was then subjected to a very rapid pressing technique and the percent of water removed was determined. Results of this test are given in Figures 15 and 16. They show very clear-cut trends with the spruce pulps where a significant decrease in the percentage of water removed in the rapid pressing is noted as time since insect attack increases. In the case of the pine pulps, there was an initial increase in the percent of water removed in rapid pressing at the green top stage, followed in the case of the whole log pulps by a steady decline in percent water removed. In the case of the pine slab pulps, the initial increase was followed by a decrease and then slight increases were determined. In comparison with control pulps, the rapid pressing measurements showed that the spruce was susceptible to decrease in efficiency with insect attack, whereas the pine was not.

Drying rate tests were carried out on a drum dryer system. In the case of the spruce pulps there was some indication that drying rate improved after insect attack. There was some indication of this also with the pine pulps, although the grey with loose or no bark stage for the slab pine pulp showed decreased drying rate in opposition to the overall trends shown.

Bauer McNett fibre classifications were carried out on the spruce slab control pulp and on the spruce slab grey stage pulp. Results are given below:

Bauer McNett Classifications of Spruce Slab Pulps

Pulp Category	+14	+28	+48	+100	-100
Control	58.2	25.7	10.0	2.6	3.5
Grey	45.1	33.9	13.1	3.8	4.1

The above data shows a clear-cut trend away from the longer fiber fraction to the shorter fibre. Differences of this type could certainly affect drainage characteristics.

It is clear from the above that the use of beetle-killed wood could have a severe impact on mill productivity from the point of view of fines production and from possible inherent low "drainability".

SUSCEPTIBILITY OF BEETLE-KILLED WOOD PULP TO MECHANICAL ACTION AT COOKING TEMPERATURE

Many Econotech projects have indicated that certain types of raw material are more susceptible to mechanical action in the pulping process (any point where mechanical or physical action takes place) resulting in lower strength pulp. A simple test was carried out at Econotech to determine the susceptibility of one sample of beetle-killed wood. The raw material chosen was the spruce grey stage slab wood, which was cooked with no mechanical action and also with mild intermittent action. Econotech work has shown that high quality chip material normally shows negligible difference between the two systems. The tests show that there was a significant difference with the beetle-killed wood, in that viscosity was reduced slightly and there was a significant drop in burst and tear strength.

CHIP AGEING STUDIES WITH BEETLE-ATTACKED CHIPS

In this study, Econotech was specifically requested by the industry to investigate whether the addition of beetle-killed chips to the mixed chips being stored at pulp mills would accelerate decomposition and wood loss. Consequently, studies to simulate chip ageing were carried out at Econotech. In this work, the ageing of 100 percent whole log control chips was compared with furnishes containing 50 percent of whole logs chip and 50 percent of the slab chips from each of the other wood categories. The chip mixtures were stored in sealed polyethylene bags at 33°C. The bags were opened every ten days to allow aeration of the chips with tumbling action. Samples were removed after one, two, and three months to determine total wood substance remaining.

Kraft pulping was carried out on the three month aged chips.

The results of the measurement of wood substance loss are summarized in Figure 17. This shows, as expected, a much greater loss of wood substance for spruce than for pine, which is in accordance with the basic wood characteristics including extractives content. Figure 17 shows that the quantity of wood substance lost on ageing for three months decreased as the beetle-attacked wood constituent moved to longer time since beetle attack. This would correspond with ageing already having been carried out on the beetle-attacked wood since death. This data would indicate that from the point of view of wood substance loss, mills should not encounter additional problems in their chip piles from the addition of beetle-killed wood. This situation could be different if the beetle-attacked wood had succumbed to rot.

No problems were encountered in the kraft pulping of the three month aged wood. Addition of active alkali was the same as that used in pulping the unaged wood. Viscosities were as expected from the components and tall oil yield was reduced for the pine but not significantly for the spruce. The total yields achieved in these cooks were normally slightly above that calculated for the component chips in their fresh state. This is as expected since loss of wood substance during ageing, which does not normally contribute to yield, effectively raises the yield on o.d. wood. However, even with the increased pulping yield, the overall yield after wood storage is lower due to the dominating factor of wood substance loss.

CTMP

Some beetle-killed wood finds its way into mechanical pulping operatiions in British Columbia. For this reason, the raw materials used in this project were used for preparing CTMP. The CTMP was prepared using a 10-minute, 100°C presteaming followed by impregnation with 3.8 percent sodium sulphite for 10 minutes at 80°C and pH 8.0. Cooking was carried out for seven minutes at 130°C. The pulps were bleached using a single-stage, two percent peroxide treatment.

The results show that tendencies in strength characteristics are not very clear-cut. However, it can be said that tear usually decreases with time since attack, this being most noticeable in the case of the spruce wood. The corresponding reduction in fibre length can be seen for these pulps. In the case of burst and breaking length, the maximum strength characteristics often appear with the green or red top samples.

Very noticeable trends were seen in the unbleached and bleached brightness figures. These show a very significant brightness drop with increasing time since death. The work does not allow the identification of the cause of brightness loss but other Econotech projects would indicate that a major factor would be blue stain content.

Owing to increased resin in green stage trees, there could be increased toxicity from mills processing beetle-killed wood.

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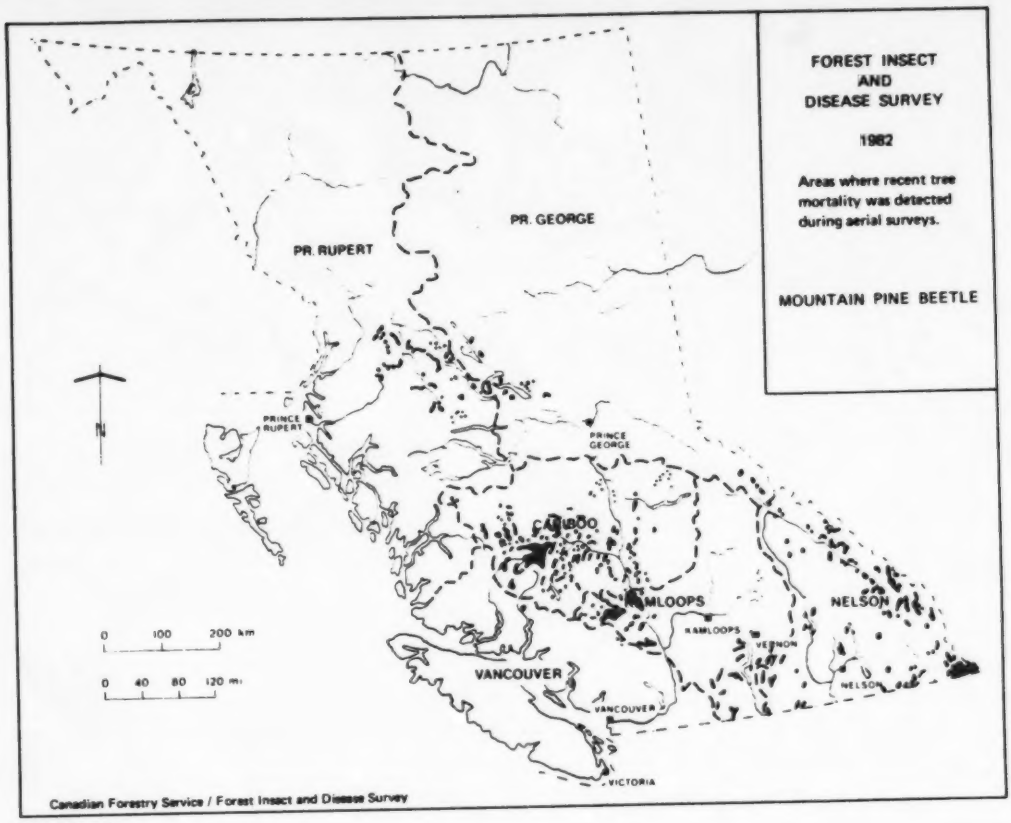


Figure 1.

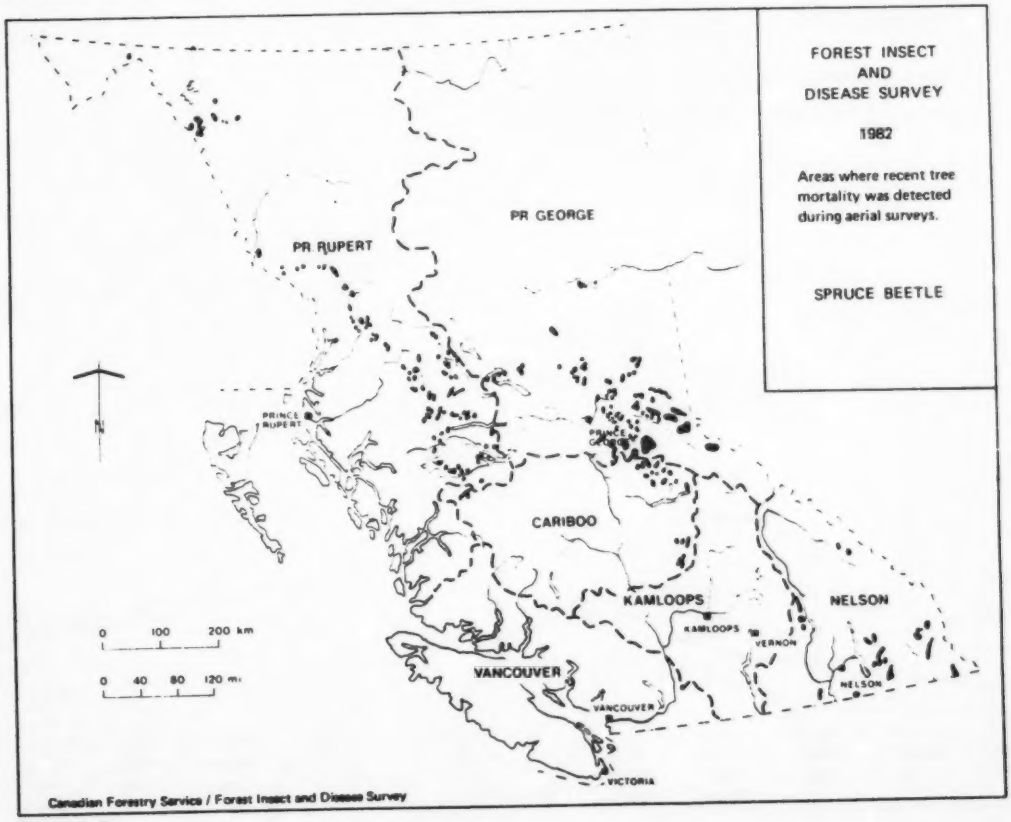
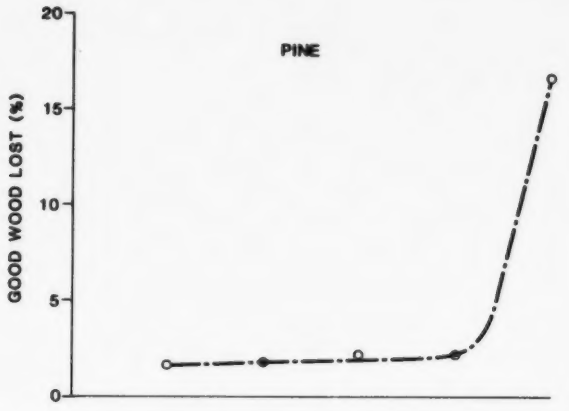


Figure 2.



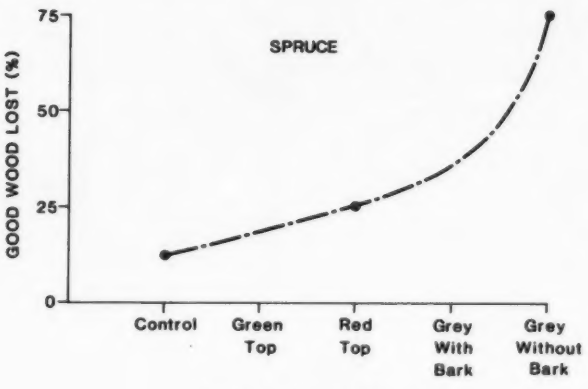


Figure 3. Cambio debarking

(See text to evaluate these figures.)

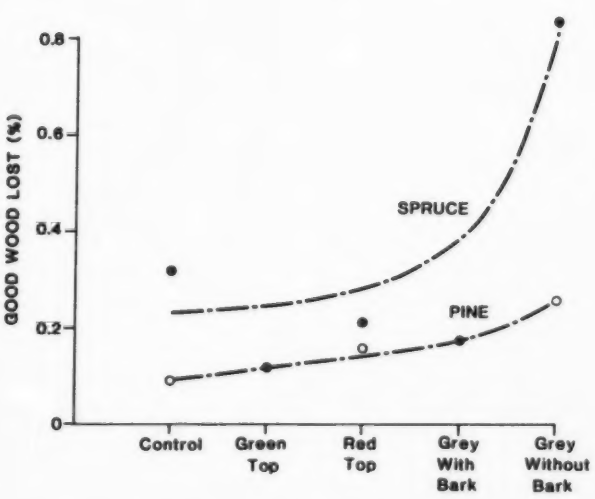


Figure 4. Lathe test for loss of good wood

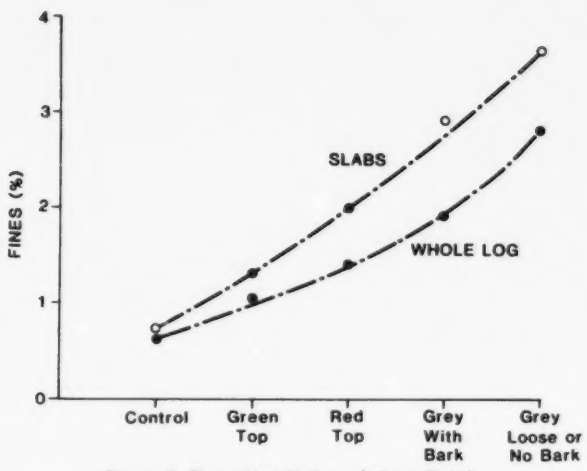


Figure 5. Pine chips % fines (-3mm R. H.)

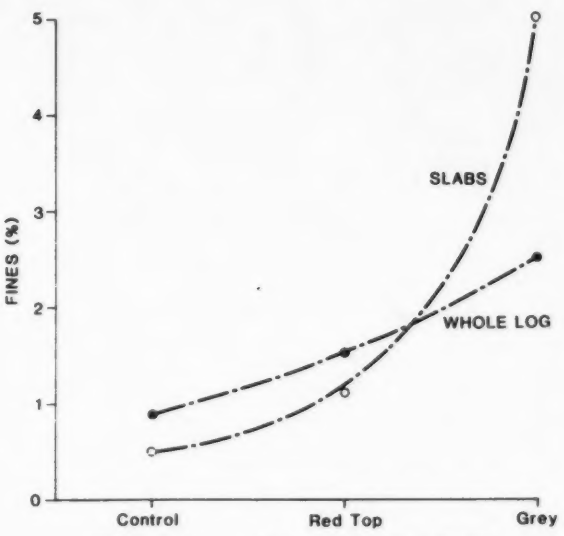


Figure 6. Spruce chips % fines (-3mm R. H.)

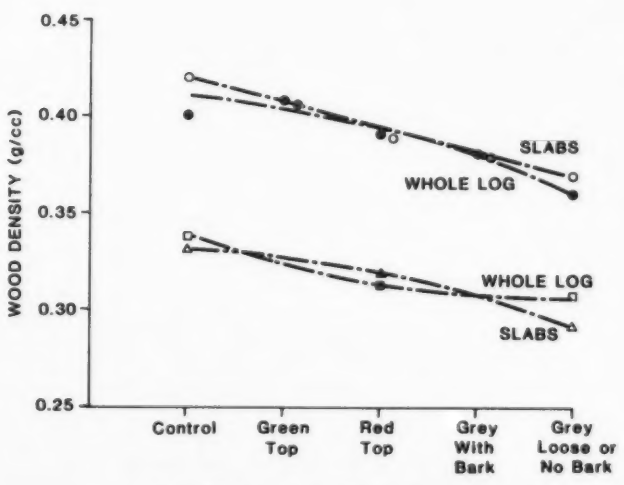


Figure 7. Wood densities vs. tree category

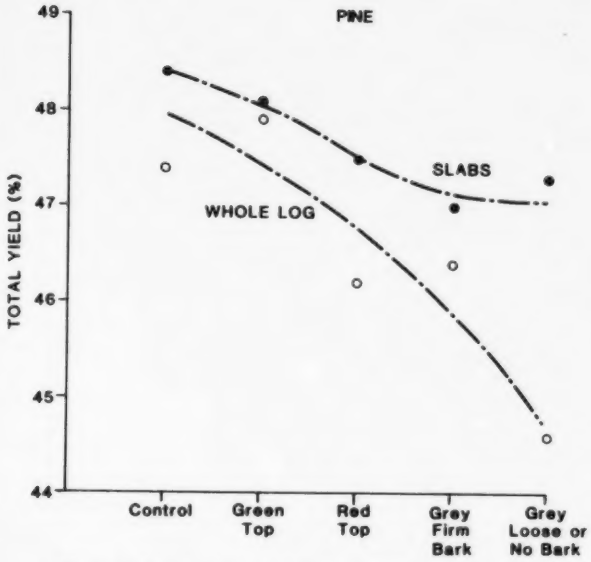


Figure 8. Total kraft yield (Data corrected to 21 K No.)

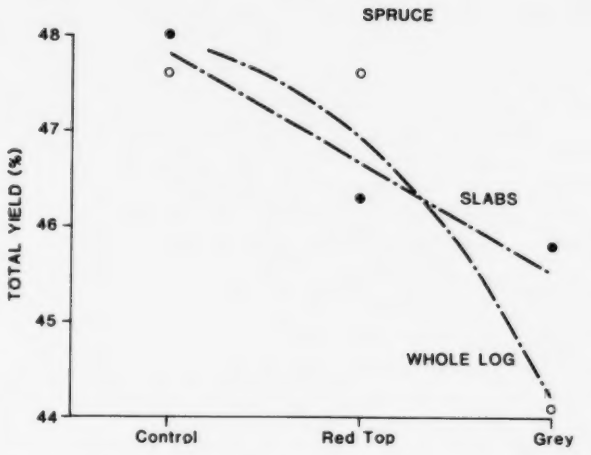


Figure 10. Total kraft pulping yield (Data corrected to 20 K NO.)

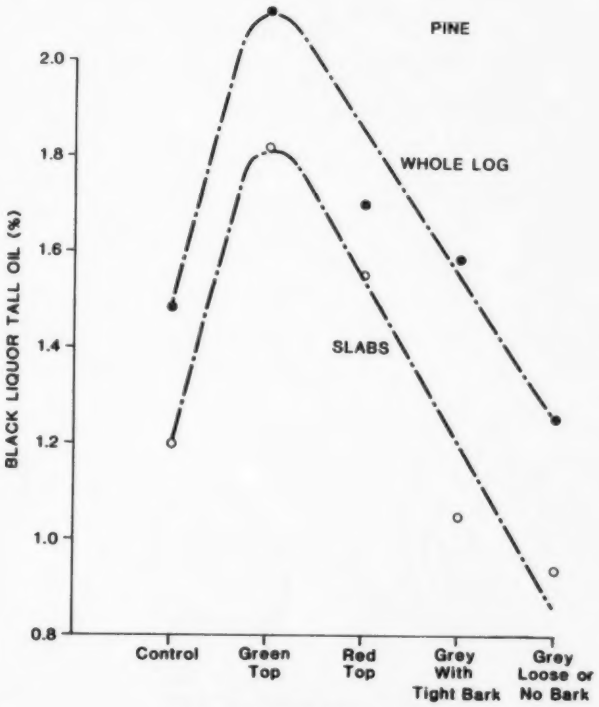


Figure 9. Black liquor tall oil

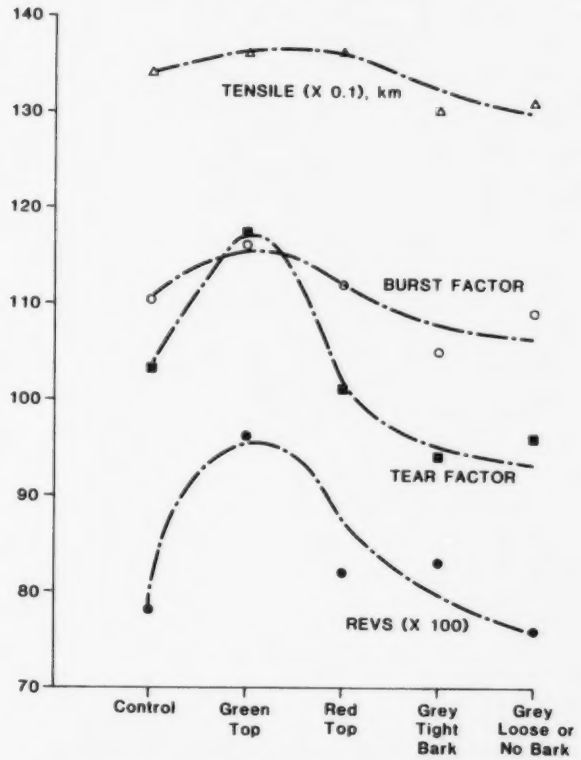


Figure 11. Pine whole log pulp bleached strength characteristics (PFI at 300 CSF)

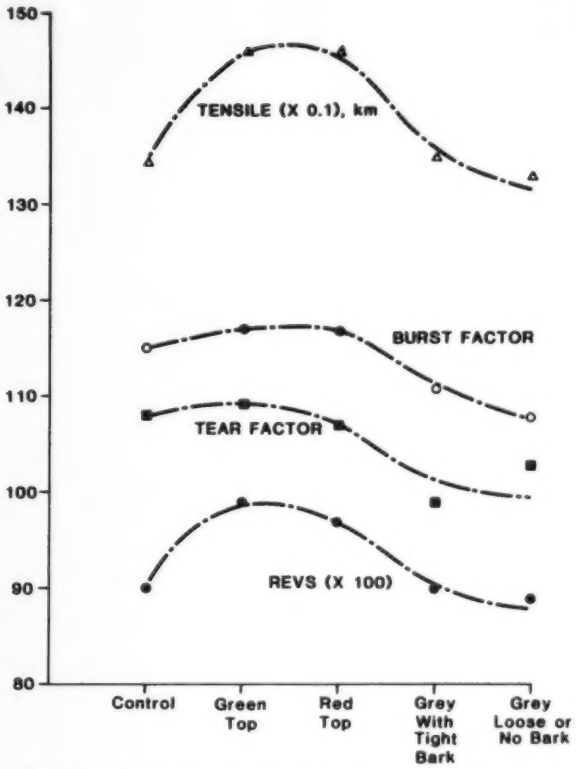


Figure 12. Pine slab pulp bleached strength characteristics (PFI at 300 CSF)

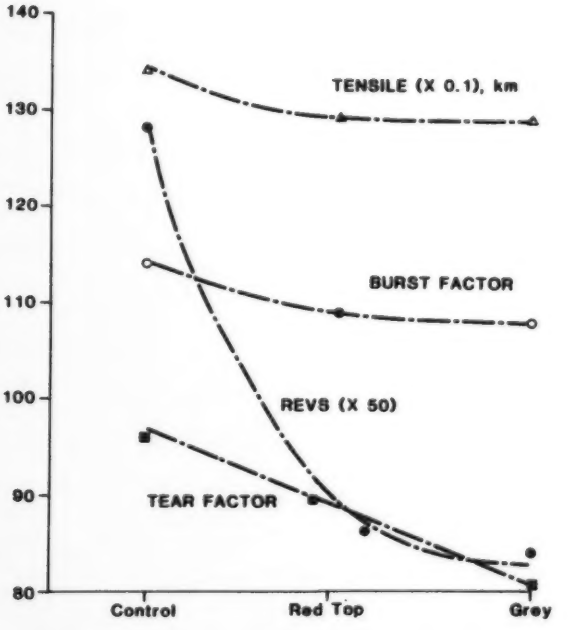


Figure 13. Spruce whole log pulp bleached strength characteristics (PFI at 300 CSF)

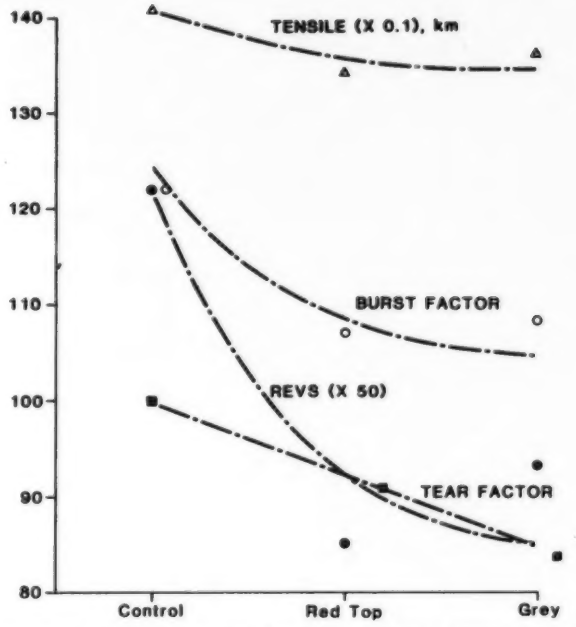


Figure 14. Spruce slab pulp bleached strength characteristics (PFI at 300 CSF)

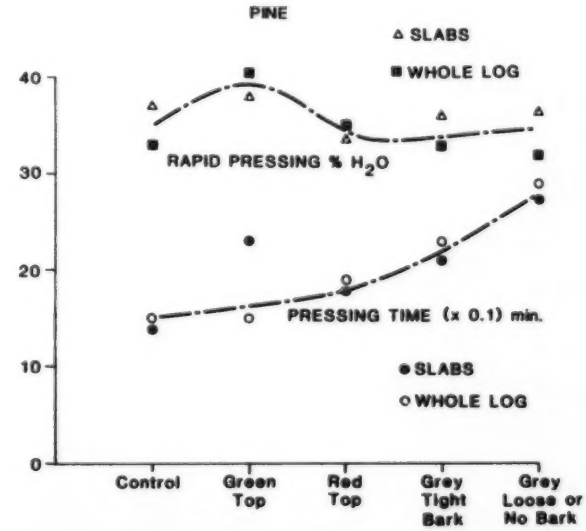


Figure 15. Pressing time and rapid pressing

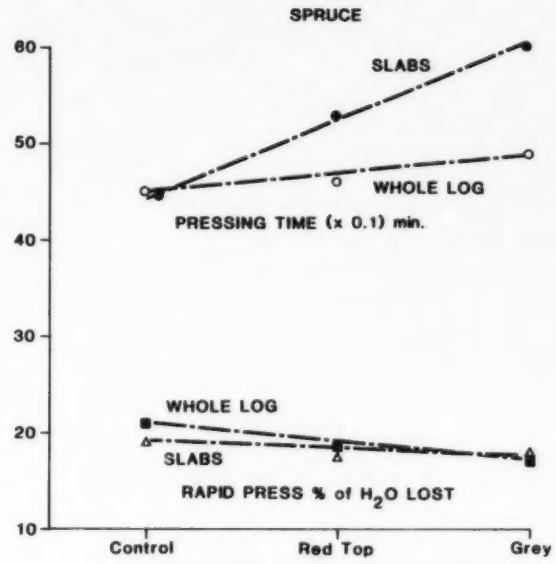


Figure 16. Pressing time and rapid pressing

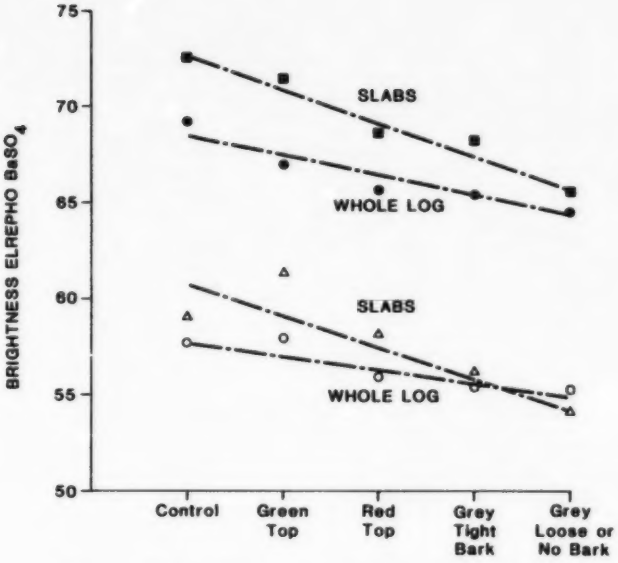


Figure 18. Pine CTMP unbleached and bleached brightness, single stage peroxide bleach

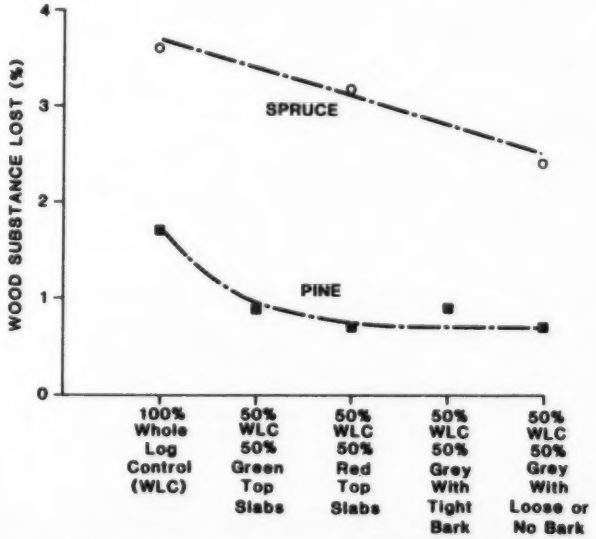


Figure 17. Ageing studies wood substance lost after ageing 3 months

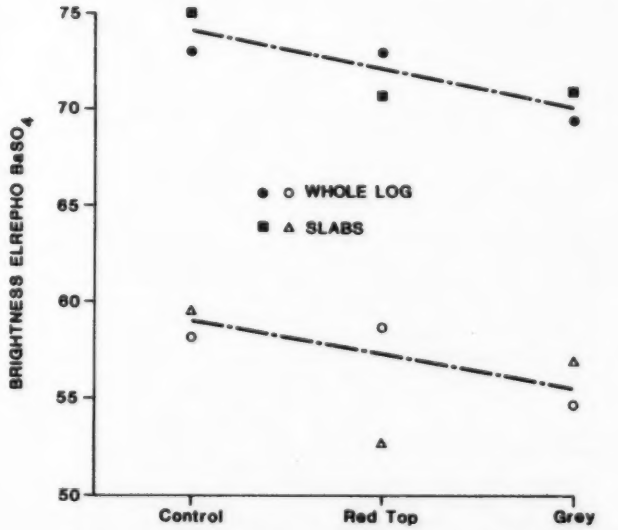


Figure 19. Spruce CTMP unbleached and bleached brightness, single stage peroxide bleach

UTILIZING LODGEPOLE PINE FORESTS OF THE 21ST CENTURY: A RESEARCH PROGRAM*

Peter Koch
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ABSTRACT

Process invention and application are the end products of research scheduled to fill the technological needs. Routes to achieving such invention vary with investigator. One route that has proven successful--and is contemplated here--calls for a step-wise procedure comprised of the following components, listed in sequence of accomplishment. Work to date is on schedule and within budget.

1982-1992 Search the lodgepole pine literature, and process literature applicable to lodgepole pine; digest this information.

1982-1984 From survey data, arrange to have the North American lodgepole pine resource tabulated and graphed by county (or survey unit). 1983-1984 Identify a few representative lodgepole pine acreages in the United States for which responsible land managers seek intensified utilization.

1983-1984 Systematically sample the North American population of lodgepole pine (variety latifolia, and less intensively, murrayanna).

1985-1987 Characterize the representative acreages identified and publish an atlas depicting and describing these acreages in such a manner that new processes can be designed specifically for them.

1985-1990 From the systematic sample of trees, characterize wood, bark, foliage, and roots of lodgepole pine as industrial raw materials.

1983-1991 Invent new processes and incorporate known processes into new manufacturing systems that should be profitable; make economic analyses of these systems; demonstrate the most promising.

1990-1992 Write a U.S. Department of Agriculture Handbook summarizing pertinent data on: the resource (with background data on physiology and silvics); characterization of representative acreages; characterization of wood, bark, foliage and roots; and processes by which lodgepole pine is converted to products, and their economic feasibility.

The needed processes should be moderate in capital, labor, water, and energy requirements, should accept trees of all diameter classes, and should yield high-value commodity products, with a high percentage of the complete tree (above and below-ground biomass) ending as salable product.

*This paper was first presented at a symposium on "Lodgepole Pine - The Species and its Management", May 8-10, 1984, Spokane, Wash., and May 14-16, 1984, Vancouver, B.C. and was published in a subsequent Proceedings by Washington State Univ., 1985.

INTRODUCTION

Lodgepole pine occupies about 5.24 billion ha (13 million acres) of commercial forest land in the United States (containing 722 million m^3 or 25.5 billion cubic feet of lodgepole growing stock and over 65 billion board feet of lodge- pole timber, mostly in Montana, Idaho, Wyoming, Colorado, and Oregon), and is the fourth most extensive timber type west of the Mississippi River. On these 5.25 million ha, a significant proportion of the trees are dead, having been killed by insects. In the Northern Region alone, a 1979 survey reported 540,862 ha (1,336,496 acres) of lodgepole pine severely infested with mountain pine beetle. Canada has a greater acreage of lodgepole pine forest type (20 million ha or 49.5 million acres, comprising 22 percent of the total forest land in Western Canada) than the United States. Most of the North American lodgepole resource is of the variety latifolia.

In both countries, much of the lodgepole pine resource is in older (60-200 years) virtually stagnated stands in which growth rate is very low and mortality very high. Typically trees are small in diameter. Perhaps half the North American lodgepole pine volume is in trees 150 mm (six inches) in diameter breast height (dbh) or smaller; trees harvested for saw logs probably average less than 300 mm (12 inches) in dbh.

Silvicultural treatments (thinning or removal and regeneration to managed stands with controlled stocking) are so expensive, and stumpage revenue so little, much of the acreage has received no treatment to accelerate growth and slow mortality.

OBJECTIVES

Present lack of technically and economically viable utilization alternatives precludes profitable harvest of lodgepole pine in large quantities. Thus foresters cannot manage the species to enhance timber growth, watershed values, wildlife habitat, esthetic quality, and recreational opportunities. In 1982, therefore, the Intermountain Forest and Range Experiment Station initiated a program to invent (or adapt) processes that would permit large-scale profitable utilization of lodgepole pine of all diameter classes on all terrain--while preserving or enhancing other resources. Another objective is to publicize the processes so they will be widely utilized, thereby making possible regeneration of forests of increased productivity.

The research program is modestly funded and is scheduled for completion over about a decade.

OBJECTIVES AND SCHEDULE FOR ACCOMPLISHMENT

Research scheduled to fill technological needs culminates in process invention and application. Routes to achieving such invention vary with investigator. One route that has proven successful--and is contemplated here--calls for a stepwise procedure comprised of the following components, listed in sequence of accomplishment.

1982-1992 Search the lodgepole pine literature, and process literature applicable to lodgepole pine; digest this information.

1982-1984 From survey data, arrange to have the North American lodgepole pine resource

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PROGRESS TO DATE

The work to date is on schedule. It is also within budget, largely because the Canadian Forestry Service, through Dr. R.W. Kennedy of the University of British Columbia, is collecting the sample trees from the Canadian portion of the lodgepole range (Figure 1).

Literature Search

Canadian efforts have also facilitated our literature search. Supply and Services, Canada, published in 1983 a lodgepole pine bibliography prepared by Reid, Collins and Associates Limited, Vancouver, B.C., in fulfillment of a contract with the Northern Forest Research Centre, Canadian Forestry Service of the Department of the Environment. The bibliography, comprising 1,318 fully indexed references, is a preliminary step toward the revision of L.A. Smithers' "Lodgepole Pine In Alberta" published in 1961. Abstracts are provided for 936 of the references. The period covered is 1970 to 1973, with a few citations that were considered standard references prior to 1970.

To date we have accumulated about 2,500 articles related to lodgepole pine and its utilization, 2,000 of which are carded in the new format of the U.S. Department of Agriculture, Forest Service citations. By the end of 1984 we should have nearly 3,000 articles carded. Digestion (analysis) of the articles will begin in 1985, when computer storage will assist in retrieval by subject. The effort will continue for about a decade.

Survey Data

Survey data on the lodgepole pine resource in Canada and the U.S. were reported at the Spokane/Vancouver symposium "Lodgepole Pine - The Species and its Management" (R.W. Kennedy, 1985; D. van Hooser, 1985).

Uneconomic Stands

During 1983 every State Forester, every Bureau of Land Management (BLM) State Forester, and every National Forest Supervisor within the United States range of lodgepole pine varieties latifolia and murrayanna was visited (except in California where lodgepole pine is not in excess supply). Each manager was asked to identify within his forest one more-or-less contiguous acreage where increased utilization of lodgepole pine would be desirable, where harvesting could proceed according to a management plant if a commercially viable utilization plan could be invented, and which the responsible forest manager would be willing to market over the next several decades. The areas identified contained not less than 2,000 acres each and might be termed "hopeless cases," where the forest manager could not visualize the stumpage being sold in the near term for conventional processing.

By February 1, 1984, 30 such representative acreages (Figure 2) were identified, totalling about 260,000 ha (641, acres), as follows:

State	Cases	Total of Representative Areas Identified in the States	
	(No.)	(M/ha)	(M/acres)
Colorado	5	68	168
Idaho	6	30	75
Montana	6	15	36
Oregon	3	4	10
Utah	1	7	17
Washington	4	89	220
Wyoming	5	47	115
TOTAL	30	260	641

The tabulated areas are only a fraction of the total acreage of economically inoperable lodgepole pine in the United States, but are representative of the problem. In March of 1984, the Nezperce National Forest identified 2,040 ha (5,040 acre) Kirks Fork area east of Elk City, Idaho, bringing the total number of cases to 31.

Sampling the Lodgepole Pine Population

The primary objective of the collection plan is to obtain three replications of disease- and insect-free specimens of 76, 152 and 228 mm (3, 6, and 9 inch) lodgepole pine (var. latifolia) at low, medium, and high elevations from 10 equally-spaced north latitudes (40 to 62.5 degrees) across 10 degrees of longitude, in such a way as to encompass the major range of latifolia (Figure 1). A secondary objective is to sample three replications of 3, 6 and 9 inch var. murrayanna at mid-elevation at four latitudes (37.5, 40, 40.5, and 45 degrees) in California and Oregon at a single longitude per latitude (Figure 1).

By the end of 1983, all the latifolia sample trees had been collected from latitudes 40, 42.5, and 50 degrees, plus six trees from 52.5 degrees. Also, half the murryayanna trees had been collected, namely, those from 42.5 and 45 degrees. The remaining trees of both varieties are scheduled for collection in 1984. Specimens, which include the central stump-root system as well as foliage, cones, branch material, and stem sections, are stored in Missoula.

Characterization of Key Problem Acreages

It is anticipated that the 30 to 35 lodgepole pine stands identified in the United States during 1984 will be mapped, photographed, and inventoried for biomass by the end of 1986. An atlas describing them should be published in 1987. The atlas will include a statement of management objectives for each stand. Because of limited funds, biomass will probably be inventoried through aerial photogrammetry supported by limited ground checks. The sampling error, especially in estimating proportions of stand in each size class, may be larger than desired. Precision must be adequate, however, to permit meaningful economic analyses of utilization alternatives.

Characterization of Wood, Bark, Foliage, and Roots

Characterization of tree components as industrial raw material is scheduled to begin in 1985 and should be concluded by 1990. Tree data will be correlated with age and diameter at breast height, elevation, latitude, and perhaps with longitude. Also, within-tree variation in properties with height and radial position will be determined. Scheduled characterization studies will include tree dimensions, moisture content, and weight and also branch size, number, angle, and weight.

Wood and bark of stems and branches will be studied to yield the following data:

- Biomass (weight and volume)
- Percent compression wood
- Spirality of grain
- Moisture content
- Specific gravity and bulk density
- Heartwood and sapwood volumes
- Anatomical dimensions, including proportions of elements, fibril angle, and resin canal frequency
- Color
- Permeability
- Swelling and shrinking characteristics
- Chemical analyses, organic and inorganic
- Velocity of sound in wood
- Heat of combustion and heat of sorption
- Fiber saturation point and hysteresis
- Friction coefficients
- Conductivity, diffusivity, and specific heat
- Thermal expansion and contraction
- Electrical resistance
- Mechanical properties of wood
- Mechanical properities of fibers

The wood and bark of the central stumproot mass will be similarly characterized. Cones will be counted and weighted, and their anatomical features and degree of serotiny noted. Data on needles will include weight, moisture content, specific gravity and bulk density, mechanical and chemical analyses, anatomical features, heat of combustion, and adhesive properties.

Process Invention

In my experience, invention of processes peculiarly adaptable to a particular tree species occurs sporadically over a long time span, and then only after continuous immersion in all facets of the subject, i.e., existing literature, the resource, the silvics and physiology of the trees, the character of the tree components (wood, bark, foliage, and roots), and the economic circumstances within the range of the trees.

The needed processes should require moderate amounts of capital, labor, water, and energy. Additionally, they should accommodate trees of all diameter classes, particularly the small diameters, and should yield high-value commodity products--selling for $300 or more per ton f.o.b. mill (ovendry basis)--with a high percentage of wood, bark, roots, and needles converted to salable products.

EXAMPLES OF POTENTIAL PROCESSES

Low-cost harvesting of lodgepole (whether as complete trees with taproot attached, aboveground whole trees, tree-length branch-free stems, random-length logs, stud logs, cordwood, chunks, or ships) is central to successful utilization of the species. Because other speakers at the symposium are addressing this aspect of the problem, I will not dwell further on potential solutions, but simply conclude that solutions must be found for small-stem harvesting on steep and/or unroaded terrain. For the past several years the Intermountain Forest and Range Experiment Station has actively worked to develop new concepts for harvesting small stems on steep and unroaded terrain, and this research will continue through the decade of utilization research herein described.

In the field of processing, two examples illustrate possibilities; the first has progressed through preliminary laboratory evaluation of the concept, while the second is still a matter for conjecture.

Fabricated Joists

Dr. Edwin Burke and I, working at the University of Montana, have demonstrated that very strong and stiff joists can be fabricated with minimally machined whole or half stems of small lodgepole pine as flanges, and 3/8-inch lodgepole plywood or flakeboard as webs (Figure 3).

When tested, the 9.5-inch-deep fabricated lodgepole joists with 4-inch half-round flanges and flakeboard webs were stronger in edgewise flexure than the Douglas-fir and larch 2 by 10's and 2 by 12's, and 9.5-inch-deep TRUSJOISTS with parallel-laminated-veneer flanges and plywood webs. Moreover, they had significantly less deflection than the 2 by 10's, and joists with laminated-veneer flanges, and were equal in stiffness to 2 by 12's. All of the lodgepole fabricated joists tested (with 2-inch round, and 3- or 4-inch half-round flanges) were significantly stronger and stiffer than the 2 by 10's.

Weights, ovendry, averaged least for the TRUSJOISTS and most for the 2 by 12's, as follows:

Item	Lineal (kg/m)	Weight (lbs/ft)
Lodgepole joists with 2-inch round flanges		
plywood webs	3.57	2.4
flakeboard webs	4.46	3.0
Lodgepole joists with 3-inch half-round flanges		
plywood webs	3.42	2.3
flakeboard webs	3.72	2.5
Lodgepole joists with 4-inch half-round flanges		
flanges and flakeboard webs	4.46	3.0
TRUSJOISTS	2.53	1.7
2 by 10's	4.02	2.7
2 by 12's	5.21	3.5

It is contemplated that long lengths (perhaps 8.5 m or 28 feet to provide clear spans in residences) of one or more styles of lightweight lodgepole joists can successfully compete with 2 by 10's and 2 by 12's, which generally are available only in lengths of 7.3 m (24 feet) or less, and which must be sawn from large logs.

Turbine Generator Direct-Fired with Wood

Much timber--particularly in the Intermountain and Rocky Mountain regions of North America--is in unroaded areas where for various reasons an extensive road system is not desirable. Managers of such timber, of which lodgepole pine is a good example, would like to market the trees to finance more intensive management and to reduce losses to insects and disease. Managers need processing plants that can be remotely located in or near the unroaded areas, and that yield high-value products transportable to markets by means other than road--a system similar to an offshore oil-well platform with pipeline to shoreline refinery. One concept could employ M. Gonsier's long-reach zigzag cable system to bring wood to the end of a haul road running perhaps 24 km (15 miles) from the center of the entire stand acreage to a nearby plant site accessible year round to workers, and in a location advantageous for connection to a regional power grid. Forest workers would travel to felling sites by fast all-terrain vehicles.

In this concept, a 10-megawatt turbine would be direct-fired with wood previously ovendried by waste heat from the system (Figure 4). The turbine would be connected to a generator and resulting electricity fed into the regional power grid. Were it possible to develop such a wood-fired turbine, overall efficiency should significantly exceed the 25 percent achievable by systems converting wood to steam and then to electricity. Moreover, the direct-fired turbine would use no water--a scarce commodity in many western forested areas.

WOOD-FIRED GAS TURBINE

The turbine, fed with wood, bark, and needles ovendried by exhaust heat, would require about 12 tons per hours; i.e., (20,000 kWh x 3,412 Btu/kWh) (8,600 Btu/dry pound x 0.33 efficiency) = 24,045 pounds per hour. If the land produced one ton of wood (ovendry basis) per acre per year, each hour of operation would remove the annual growth increment from 12 acres. To sustain the operation in perpetuity would require 101,088 acres (12 acres/hour x 24 hours x 351 days/year). If stumpage, harvesting, and truck-haul costs total $35 per ovendry tone, and 1.2 pounds of wood are required to generate one kWh, the wood cost per kWh = $0.021. If the power sold at $0.085 per kWh, then $0.064 per kWh is available for profit, depreciation and operating costs exclusive of wood cost; this amounts to $10, 782, 720 per year if the plant operates at capacity 50 weeks per year. In metric units, the plant would consume about 10.9 t of wood and bark (ovendry basis) per hour, and would require a land base of 10,909 ha for operation in perpetuity.

EVALUATION OF POTENTIAL PROCESSES

In an effort of this kind, researchers must decide whether their primary clients are tree owners, processing plants, or consumers. I early decided that our purposes were best served, and goals considerably clarified, if the tree owners were considered the primary clients. Having made this decision, one method of evaluating existing or potential processes is in terms of value f.o.b. mill shipping dock of each commodity manufactured by the mill related to the number of dry tons of complete tress (roots, foliage, bark, branches, and stems) required--in the factory, or left behind in the wood--to make the commodity. The idea is illustrated with a simplified example.

Suppose a pulp mill manufactures unbleached kraft linerboard from bark-free stemwood (to a 75 mm top diameter) of lodgepole pine, and that the yield of linerboard is 50 percent of dry weight of dry, bark-free stems entering the mill, and that the bark-free stem to this top diameter represents 60 percent of the ovendry weight of each complete tree. If the linerboard sells for $300 per ovendry ton f.o.b. mill, and the mill sells no other product, this $300 amounts to $300 x 0.6 x 0.5 or $90 per ovendry ton of complete tree on the forest property used to supply the mill.

Results of ranking manufacturing processes by this yardstick are shown in Table 1. Thus pulp chips f.o.b. sawmill have a value per ton of complete tree, ovendry of only $12, split residential firewood f.o.b. woodyard $19, methanol f.o.b. manfacturing plant $45, 2 by 4 studs plus pulp chips f.o.b. sawmill $6-, unbleached kraft linerboard f.o.b. pulpmill $90, electricity generated by a wood-fired steam turbine $91, structural flakeboard $108, electricity generated by direct-wood-fired turbine-generator $120, and truss flanges fabricated from minimally machined whole stems or half-stems of trees $120.

Obviously, gross revenue data are insufficient to rank investment opportunities; Table 1 is difficult to interpret, but raises interesting questions. For example, if a forestland owner perceived that he could market the annual growth increment of his forest by building and operating one of two plants incorporating proven technology--

> either a kraft linerboard plant using bark-free stemwood only, pulped with a 50 percent yield, with product sold for $300 per ton, ovendry basis,
>
> or a steam-turbine-driven generator plant utilizing all the above-ground tree biomass--but not the roots--and operating it at 25 percent overall efficiency, with his electricity selling to the regional power grid at $0.085 per kWh,

which should he choose? Table 1 indicates that the forestland owner--also the manufacturing plant owner in this case--would receive gross sales from the linerboard plant of $90 per ton of complete tree, or gross sales from the electricity generation plant of $91 per ton of complete tree. Both plants would be very expensive, but possibly a stand-alone generating plant is less complex and expensive than a linerboard plant. Perhaps he would be better advised to make fabricated joists (Figure 3) in a simpler but more labor-intensive plant, for a gross sales return of $120 per ton of complete tree, ovendry basis

CONCLUSION

The program of research on utilization of lodgepole pine in North America--including characterization data so obtained, and concommitant interest focussed on lodgepole--if executed as planned has high probability of stimulating invention of harvesting and conversion processes both profitable and appropriate for improved management of the species.

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Van Hooser, D. and C.E. Keegan III. 1985. Lodgepole pine as a commercial resource in the United States. IN: Proc. of Syposium: Lodgepole Pine - The Species and its Management. Wash. State Univ., Pullman. p.15-19.

Table 1.--Potential lodgepole pine commodities ranked according to the gross sales revenue of the product per ton, ovendry, of complete trees required to fabricate the commodity

Commodity	Percent of complete tree[1] used	Gross sales revenue per ovendry ton of the commodity	Gross sales revenue from commodity, per ton, ovendry, of complete tree
	(percent)	----------dollars----------	
Pulp chips f.o.b. sawmill	60	20	12
Residential firewood, split and loaded on truck f.o.b. woodyard	54 (0.6x0.9)	35	19
Methanol via oxygen-blown gasification and water-shift reaction	60	75[2]	45
2 by 4 studs plus pulp chips	27 (0.6x0.45) 20 (0.6x0.33)	233 for studs 20 for chips	64 (total)
Unbleached kraft linerboard	30 (0.6x0.5)	300	90
Electricity via steam turbine	85	107[3]	91[4]
Structural flakeboard f.o.b. mill	54 (0.6x0.9)	200	108
Electricity via direct-wood-fired turbine	85	141[3 4]	120[4]
Fabricated truss flanges (Figure 3)	30 (0.6x0.5)	400[5]	120[5]

1 Biomass percentages of complete trees are approximated as follows (ovendry-weight basis): central stump-root system, 15%; bark-free stem to merchantable top, 60%; stem bark, 10%; branchwood and branchbark, 10%; foliage, 5%.

2 Plant-gate price of methanol, $0.13/l ($0.50/gallon); 45 percent yield on ovendry wood, by weight.

3 Assume gross revenue from electricity at $0.85/kWh with efficiency of 25%, (25% of the heat energy in the wood fed the boiler is converted to electrical energy leaving the generator). Thus 721g (1.59 pounds) of wood, ovendry basis, are required to generate 1 kWh of electricity.

4 If efficiency could be raised from 25% for a steam-driven turbine-generator system to 33% for a direct-wood-fired turbine-generator set, this revenue would increase to $120.

5 Plus some revenue from chips or flakes.

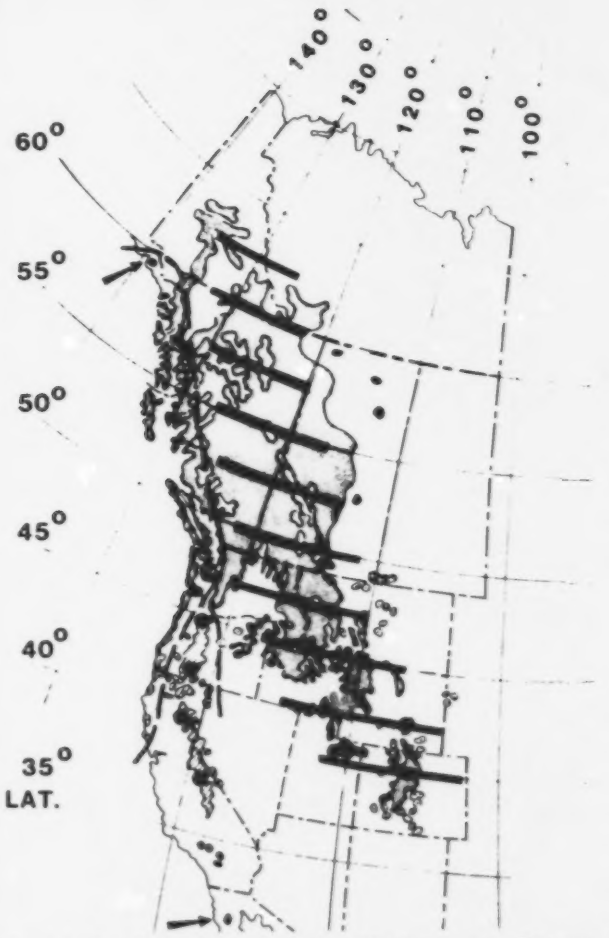


Figure 1.–Sampling zones superimposed on Little's range map of lodgepole pine in North America. Variety *latifolia* is mapped to the right of the dashed lines, *murrayanna* between them, and *contorta* (shore pine) will not be sampled because of its small potential for commercial use. The two arrows indicate outlying populations in north and south.

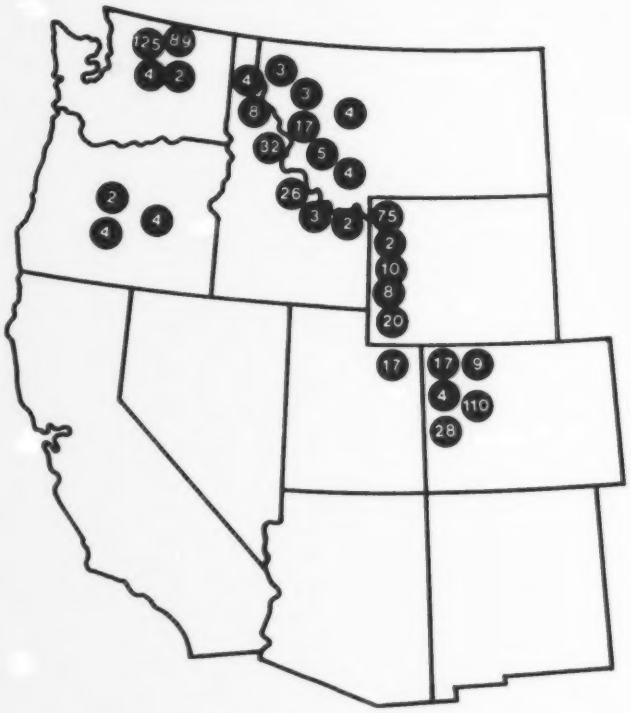
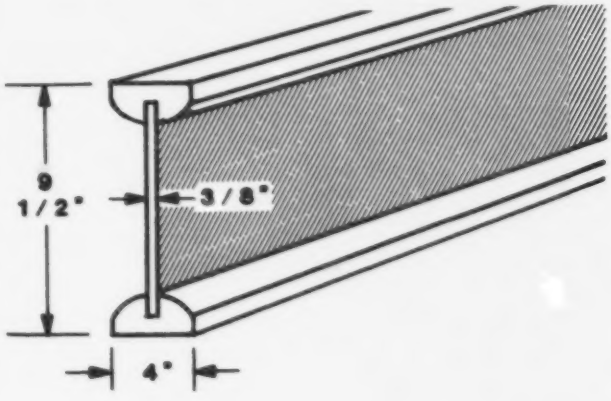
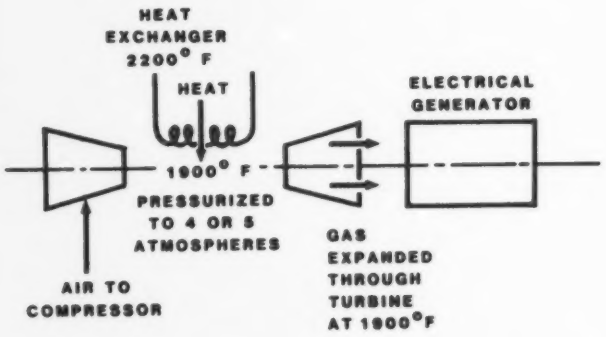


Figure 2.–General locations of 30 representative "hopeless case" acreages of lodgepole pine on public lands. The circled numbers, located by state, indicate thousands of acres.



- FLANGES OF HALF-ROUND STEMS
- WEB OF FLAKEBOARD

Figure 3.–Lodgepole pine joist. Half-round stems measure 102 mm (4 inches) in diameter inside bark at the small end before edging. In metric terms the joist measures 241 mm deep with web thickness of 10 mm.



WOOD-FIRED GAS TURBINE

Figure 4.–Turbine-generator set direct-fired with wood, using a heat exchanger to expand compressed air driving the turbine. Heat exchangers operating at 1200°C (2200°F) have not yet been commercially developed. Other configurations that do not require such high temperatures are possible.